Useful Information

for

Cotton Manufacturers.

Compiled and Issued

by

Stuart W. Cramer,

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Contractor for

Cotton Mill Machinery

and Equipment.

Providence, R. I. Charlotte, N. C. Atlanta, Ga.

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Summary of Contents

Volume I.

Section I.:

The Textile Machinery ordinarily installed in a yarn or cloth mill on plain work.

Appendix.

Volume II.

Section II.:

Sundry and Miscellaneous Equipment and Power Plants.

Appendix.

Volume III.

Section III.:

Dyeing and Special Finishing Machinery.

Section IV.:

Cotton and its Manufacture, Mill Architecture and Engineering, with General Technical and Miscellaneous Information.

Volume IV.

Section V.:

Air Conditioning, with special reference to the Cramer System of Air Conditioning and to the Cramer Automatic Regulator for Heating and Humidifying Systems.

Index.

An Alphabetical Index for the first three volumes will be found at the end of Volume III.

The Index for Volume IV. will be found at the end of this Volume.

Preface to Volume IV., Second Edition.

In the equipping and starting up of so many mills, my interest in the effect of varying humidities has been excited by noting the striking results of changeable atmospheric conditions. All kinds of troubles experienced in the running of machinery that we have furnished, particularly troubles in starting up new machinery, are shifted on to us as "machinery men." Careful study and observation covering a number of years have made it quite clear that the large majority of these troubles is directly traceable to variations in humidity and temperature, from hour to hour and from day to day.

This conclusion was forced upon me even before sufficient data had been collected to prove the point; for—

Why is it, in a mill making the same thing the year through, with the same cotton, the same organization of machinery with reference to speeds, drafts, weights, and other like details, that the work runs differently from day to day, and even that overseers complain that the work does not run equally well on days that appear to be just alike?

And why is it that excessive power consumption, especially of spinning and twisting, occurs in spells of damp weather, and during the early morning hours in all weather, particularly on Monday mornings?

These and many kindred phenomena, some more and some less well known, have been included in the scope of my investigations, the most material and pertinent results of which are:

(1) That the behavior of textile fibres in process of manufacture depends upon the physical condition of each individual fibre.

(2) That the only physical change in the fibre itself not contemplated in the processes of manufacture is that produced by its hygroscopic property.

(3) That the only outside agencies that affect its hygroscopic property are changes of temperature and humidity.

(4) That its power of hygroscopically absorbing or losing moisture under varying conditions of humidity and temperature, not only affects its weight, elasticity and strength, but also its dimensions, appearance and even conformation.

Under the present high state of development of textile machinery, and the skill easily obtainable for the proper operation of it, the difficulties properly chargeable in manufacturing to those instruments are quickly hunted down and disposed of. But there yet remain these other difficulties,

which are neither the fault of the machines nor of those who operate them, and which are the most exasperating because of their intangibility and of the fact that their causes have not heretofore been generally appreciated.

Starting out, however, with a consideration of the fibre itself and of the changes it undergoes under varying conditions of heat and moisture: noting the effect of its changes in dimension and conformation as affecting the setting of rolls, as affecting the tension of stock passing through machinery in the different processes, as affecting the traveller pull in spinning, and as affecting the strength of the yarn itself in many operations which it undergoes—the parts that temperature and humidity play in manufacturing are strikingly apparent, and the advantages to be gained by maintaining those conditions as nearly uniform as possible, go without saying.

Reduced to its lowest terms, atmospheric changes cause corresponding changes in the amount of moisture contained in fibres exposed to such changes; changes in the amount of moisture in those fibres cause corresponding physical changes in them which require different settings of the machinery, changes of weights, travellers, etc., all of which are impracticable to make every time these atmospheric variations occur, thereby accounting for excessive breakages and loss of production at one time as compared to another.

Naturally enough, the time I have had to devote to it and the study I have had to make of this subject in connection with my machinery business has resulted in the evolution of a system for, what I term, "Air Conditioning;" one that in my judgment best meets the requirements of the case, not only in the method of producing and distributing humidity uniformly in mills, coupled with ventilation, but also a system of Automatic Regulation of Humidity and Temperature, flexible enough to meet changing conditions rapidly and effectually, adaptable enough to fit any type of humidifying apparatus, simple enough in design to be easily understood, and durable enough in construction to be easily taken care of.

In attempting to write a catalogue, I am confronted with the fact that there is more written of a purely advertising nature than of technical character.

The apparent simplicity of the proposition has tempted so many to enter the field that the mill man of to-day is confronted by a number of different types of outfits from which to select. He is made the object of advertising campaigns in which it is exceedingly difficult to distinguish fact from fancy; catch-penny phrases and epigrams abound, scientific terms are brought into requisition to designate operations that never take place, and it is possible to understand some of the remarkble claims made, only upon the assumption that

either they are to be taken on faith or that the purchaser is not enough of a specialist to disprove them.

While feeling that my interests will be best served by the dissemination of as much information as possible, and while willing to show the state of the art as I see it, I realize that anything I say will, too, be open to the charge of its not being disinterested, for I am also a manufacturer of such apparatus. Yet, believing that the reception of Volumes I., II., and III. of my books of "Useful Information for Cotton Manufacturers," which, while they were avowedly written for advertising purposes, still found favor enough to be retained by most of the recipients as general reference books, I feel that I may venture to write up Air Conditioning in a similar manner, and to present it as Volume IV.

The most substantial contribution to the literature on the subject is by Mr. W. D. Hartshorne, of the Arlington Mills, Lawrence, Mass., to whom I am indebted for permission to quote. His paper on "Some Comparative Data on Moisture in Cotton and Worsted," read before the New England Cotton Manufacturers' Association at Atlantic City, September 21, 1905, is worthy of the study of any one interested in this subject.

And finally, it is not out of place for me to express my appreciation of the assistance rendered me by the Manomet Mills, at New Bedford, Mass., in a careful analysis of the conditions existing in their new No. 2 mill, the latest and largest complete installation that has been made of my appatus,—a 75,000 spindle mill on medium and fine combed yarns.

STUART W. CRAMER.

March 31, 1909.

ANNOUNCEMENT.

The above cut illustrates **our new building on Court House Square, Charlotte, N. C.**

Our **general** and **engineering offices** occupy the second floor, **draughting room** and **experimental laboratory** the top floor. In the first story of the front or office building is the **instrument shop** in which the **Cramer Automatic Regulators** are made.

The **Cramer Air Conditioners and Humidifiers** are manufactured in the **sheet metal shop** in rear. (Not shown.)

The equipment of these shops comprises the best machinery obtainable and everything required to turn out perfect goods interchangeable in parts and excellent in workmanship.

Attention is also called to **our offices in Providence, R. I. and Atlanta, Ga.**

STUART W. CRAMER.

THE CRAMER SYSTEM OF AIR CONDITIONING.

(Trade Mark.)

A system comprising an apparatus for Air Conditioning as scientifically designed and mechanically constructed as the machinery for spinning and weaving or that for any of the other technical processes carried on in a modern manufacturing establishment wherein uniform atmospheric conditions contribute to the quality and quantity of its product, and wherein large numbers of work people are congregated whose health, comfort and efficiency depend upon the purity and freshness of the air they breathe.

A system embodying the results of many years of study and intimate contact with the requirements of the case acquired in the designing of approximately one hundred and fifty cotton mills and the furnishing of the complete outfits of machinery and other equipment for almost all of them, as well as that for nearly as many more designed by other engineers,—the whole aggregating between two and three million spindles.

Simple in Construction, Efficient, Durable, Air Cleansing and Sanitary.

Both Humidifying and Heating Systems Automatically Controlled to any Desired Standard and Each Room Separately.

SECTION V.

I. Air and its Behavior under Changing Conditions of Humidity and Temperature.

II. Atmospheric Conditions affecting Health.

III. Atmospheric Conditions affecting Manufacturing.

IV. Regain and Hartshorne's Tables.

V. Air Conditioning in General.

VI. Cramer System of Air Conditioning.

VII. Cramer Automatic Regulator for Humidifying and Heating Systems.

I.

AIR AND ITS BEHAVIOR UNDER CHANGING CONDITIONS OF HUMIDITY AND TEMPERATURE.

Air Composing the Atmosphere.

Air is a mixture of oxygen and nitrogen in the following proportions: By volume, 20.91 parts oxygen to 79.09 parts nitrogen; by weight, 23.15 parts oxygen to 76.85 parts nitrogen. Each of these figures, however, is subject to a variable correction of less than 1%, due to the fact that air always contains other constituents such as carbonic acid gas (CO_2), ammonia, ozone, hydrogen, water vapor, dust, and traces of rare gases such as argon, helium, etc.

The part each of the above plays in supporting life will be discussed in another chapter; for the present it is sufficient to say that all except the solid impurities are gases, even the water or aqueous vapor being perfectly absorbed and existing, therefore, as a colorless, perfect gas.

How Moisture Exists in Air—i.e., in Space.

It is perhaps in order to again emphasize the fact that air is not an elementary gas but merely a mixture, and yet a peculiar fact exists with reference to its capacity for holding moisture. Whereas any of its elements may be changed without apparent outward effect, the amount of vapor that can be retained in it is limited and even varies with the temperature. The U. S. Weather Bureau explains this apparent anomaly by saying that the presence of moisture in any given space is independent of the presence or absence of air in the same space except that the air retards the diffusion of the vapor particles. It is more correct to say the space is saturated than that the air is saturated. And so it appears that we may speak of a cubic foot of saturated aqueous vapor in which it exists at its greatest density, and of percentages of saturation in which it appears in correspondingly attenuated condition. Still, as custom sanctions usage and to prevent confusion, in this book the air will be spoken of in connection with humidity, bearing the above explanation in mind, of course.

Capacity of Air for Holding Moisture.

The amount of saturated aqueous vapor that can exist in any given space depends entirely upon the temperature, under normal conditions. In the psychrometric tables at the end of this chapter the actual humidity in grains per cubic foot of air at saturation, or 100%, is given. The number of grains per cubic foot at any temperature for different percentages of relative humidity is obtained by multiplying

the percentage of relative humidity by the figures given for saturation at that temperature. For example, 3.99 grains are found to be contained in a cubic foot at 70° temperature and 50% relative humidity by multiplying 7.98 grains for saturation taken from the table opposite 70°, by 50%. Differences in barometric pressures affect humidity calculations slightly, but the differences are negligible for this work.

Interdependence of Humidity and Temperature.

It is thus seen that all questions of humidity and temperature are strikingly interdependent, and that the regulation of humidity for considerations of either health or those favorable to manufacturing carries with it the necessity for corresponding attention to the question of temperature.

Thermometers.

Ordinary temperatures are usually indicated by thermometers, and high temperatures by pyrometers. Thermometers are either mechanical (as they are termed), electrical, or of the well known glass tube type with mercury, alcohol or other expansible fluid therein. The most reliable ones and those requiring the least care are undoubtedly the glass tube types. A consideration of thermometers in detail is pertinent only so far in as they enter into the construction of hygrometers, under which heading they will be taken up again.

Thermometric Scales.

The Fahrenheit and Centigrade scales are the ones usually used, the former especially in the U. S. and Great Britain. The melting point of ice is 32° F. and 0° C.; the boiling point of water is 212° F. and 100° C. Conversions from one scale to the other are therefore simple and quickly made:

1° F.=5/9° C. and 1° C.=9/5° F., hence—
Any temperature F.=9/5 x Temp. C. + 32°, and
Any temperature C.=5/9 (Temp. F.—32°).

Absolute Temperature.

For scientific calculations, it is often necessary to use absolute temperature. Without entering into an elaborate explanation, it is sufficient only to say that absolute temperature is purely a theoretical conception, one in which it is assumed that it is possible to continue the cooling of a perfect gas until its volume is diminished to nothing. It is 459° F. and 273° C. below zero, disregarding fractions; or 491° F. or 273° C. below the freezing point of water. It is sufficient only to say that this is based upon the fact that air expands or contracts 1-491 of its volume for each degree rise or fall of temperature respectively considering the volume of air at 32° F. or freezing, and 30 inch barometer as unity or standard; it is therefore quite conceivable that if the air could be cooled 491° that its volume would have diminished to nothing.

Humidity, Relative and Actual.

Dew Point.

Humidity is stated as either relative or actual. Complete saturation of the air with moisture is stated as 100, and lesser amounts by percentages.

Actual humidity is the weight in grains of the vapor per cubic foot of air.

The dew point for any temperature and humidity is the temperature to which the air may be cooled when precipitation takes place.

Means for Measuring Humidity in the Atmosphere.

Dew Point Apparatus.

Hygrometers.

There are a number of methods, more or less exact, of ascertaining the amount of moisture in the air. Regnault's dew point apparatus is very exact in the hands of experts, but for ordinary purposes quite out of the question; as its name indicates, dew points are obtained by it, from which humidity and other characteristics are calculated by formulas.

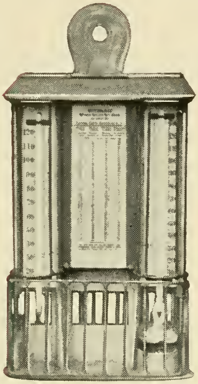
The best known means for measuring humidities is, however, by the use of hygrometers. Those comprising a wet and dry bulb thermometer have been deservedly popular until the introduction of the psychrometer. In the hygrometer the two thermometers are generally placed 3 to 4 inches apart in an upright position, the bulb of the dry thermometer exposed and that of the wet one covered with thin muslin or silk boiled in alkali to make them as hygroscopic as possible. Below the wet bulb is a reservoir of water into which a wicking of yarns or woven stuff hangs pendant from the covering on the wet bulb which is thereby kept moist by capillary attraction. The dry bulb indicates the temperature of the air, while the wet bulb indicates the cooling effect of the evaporative power of the atmosphere. As the amount of evaporation is in proportion to the dryness of air, it is obvious that the difference between the readings of the two thermometers, termed the "depression of the wet bulb," in conjunction with suitable tables, furnish a measure of the humidity at that temperature.

For the convenience of those who may desire to use hygrometers, the accompanying tables at the end of this chapter will be found concise and condensed.

Such hygrometers are what may be termed continuous indicating, and were it not for certain drawbacks would be ideal instruments: these drawbacks are indicated by the precautions that are necessary and usually given for their use, viz.:

"Hygrometers should be exposed in the shade free from air currents.
The covering of the wet bulb must be very thin.
The bulb must be constantly moist.
The supply of water must be ample in dry weather.
Use distilled, rain, or softest water procurable, for wet bulb.
When lime deposits from use of hard water, change muslin and wick.
Dust and blacks must not be allowed to accumulate on muslin.
Wash occasionally while in use."

Even if distilled water be used, the dust in the atmosphere will cause encrustation very quickly and floating bacteria will cultivate a growth of stain or even slime in a day or two at times. Changing the wicks and coverings daily is the only guarantee of accuracy of indication, a troublesome, fussy little job that is generally put off as long as possible, with the result that few hygrometers are anything like in correct working condition, as can be easily verified in the best manufacturing plants in this country or abroad.



The accompanying cut illustrates a wet and dry bulb hygrometer that is of excellent construction and design.

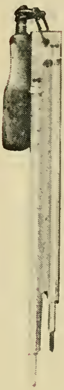
Many attempts have been made to devise hygrometers that would take the place of this wet and dry bulb type of instrument, but they have all been ignominious failures, they generally depending upon the behavior of vegetable or animal fibres or materials under different atmospheric conditions. For convenience, this type of hygrometer may be termed the mechanical type. Its lack of trustworthiness is due to two causes: the first being that humidity affects them to a different extent at different temperatures; and the second, the susceptibility of the surface pores of the sensitive substances to being choked up by dust, lint, etc., a thin coating of which causes the indications to become sluggish and erratic.

The standard hygrometrical tables in use, the world over, are those prepared by Mr. James Glaisher, F. R. S., of the Royal Observatory, Greenwich, England. The tables I append to this chapter are condensed and abbreviated forms of Glaisher's tables, complete enough for mill use, but shorn of the detail and accessory information that characterize that splendid piece of scientific work.

Psychrometers.

The most reliable instrument is the Sling Psychrometer brought out by the U. S. Weather Bureau and adopted by it for use as the standard instrument for observers at all stations. It may be termed the scientific equivalent of the corresponding type of hygrometer. Its greatest drawback is that it is not a continuous indicating instrument, yet as it too requires a covering on the wet bulb, that objection is its salvation, for each time the instrument is used it is natural and easy to see that the covering is clean and properly moistened.

To quote Professor Marvin, who prepared the Psychrometric Tables issued by the Weather Bureau—



"This instruments consists of a pair of thermometers, provided with a handle, as shown in the figure, which permits the thermometers to be whirled rapidly, the bulbs being thereby strongly affected by the temperature of and moisture in the air. The bulb of the lower of the two thermometers is covered with thin muslin, which is wet at the time an observation is made. In special cases, rotary fans, or other means, may be employed to move the air rapidly over the thermometer bulbs. In any case satisfactory results can not be obtained from observations in relatively stagnant air. A strong ventilation is absolutely necessary to accuracy.

"To make an observation, the so-called wet bulb is thoroughly saturated with water by dipping it into a small cup or wide-mouthed bottle. The thermometers are then whirled rapidly for fifteen or twenty seconds; stopped and quickly read, the wet bulb first. This reading is kept in mind, the psychrometer immediately whirled again and a second reading taken. This is repeated three or four times, or more, if necessary, until at least two successive readings of the wet bulb are found to agree very closely, thereby showing that it has reached its lowest temperature. A minute or more is generally required to secure the correct temperature.

"When the air temperature is near the freezing point it very often happens that the temperature of the wet bulb will fall several degrees below freezing point, but the water will still remain in the liquid state. No error results from this, provided the minimum temperature is reached. If, however, as frequently happens, the water suddenly freezes, a large amount of heat is liberated, and the temperature of the wet bulb immediately becomes 32°. In such cases it is necessary to continue the whirling until the ice-covered bulb has reached a minimum temperature.

"The tables are strictly applicable only to wet and dry bulb temperatures as determined by means of the sling, or whirled psychrometer, or some equivalent form of apparatus, in which the wet bulb especially is subjected to a strong current of air, the velocity of which is not less than 15 feet per second."

The psychrometric tables appended to this chapter are simply a rearrangement of the Weather Bureau tables, that I prepared for the especial convenience of mill men.

As psychrometrical tables are used in conjunction with indications of the thermometers in Cramer Automatic Regulators, both dry and wet bulb temperatures are given rather than "depressions of the wet bulb," thereby dispensing with all calculations and enabling direct readings to be used when referring to the tables.

Thermostat.

—

Hygrostat.

—

Cramer Automatic Regulator.

As is generally known, a thermostat is a thermometer so constructed as to actuate regulating apparatus for maintaining a predetermined temperature by controlling a heating system or device; they are of as varied types as are indicating thermometers; in fact, they may be termed regulating or actuating thermometers.

A hygrostat performs the same functions for regulating humidity that a thermostat does for temperature.

Attempts have been made to make hygrostats of the mechanical types, similar to the same type of hygrometers, but for the same reasons they have failed.

The Cramer Automatic Regulator, however, is a combined thermostat and hygrostat, with all the accuracy and stability of the wet and dry bulb types of instruments, and furthermore dispenses with the covering on the wet bulb and its attendant care and annoyance.

(Type R. Regulator)

These instruments will be fully described in Chapter VII. They are made of different types, so as to suit all conditions. The principles involved in their construction, which are covered by basic patents, are the same in each, viz.:

(1) Whatever types of thermometers or thermometric substances are used, there is a dry bulb member and a wet bulb member.

(2) The wet bulb temperature is attained without the use of rags or wickings by simply saturating or super-saturating the air and directing it upon the exposed wet bulb member.

As with hygrometers and psychrometers, the difference between the indications of the dry and wet bulb thermometers is the "depression of the wet bulb" upon which hygrometrical and psychrometrical tables are based; so, the dry and wet bulb members in the Regulators, likewise, co-ordinate to maintain any desired humidity on a basis of the "depression of the wet bulb."

Also, the wet bulb temperatures are dew points of the air issuing from humidifiers that deliver saturated air; hence the terms "Wet Bulb Control" and "Dew Point Control" by which the functioning of these Regulators is occasionally designated, according to the system of humidification used.

In dew point control, the very doubtful assumption is made that the temperature of the saturated air blown into the room is the same as the dew point of the air in the room,—which will also be discussed in Chapter VII.

Heat.
Heat Units.

Heat is a condition of matter caused by the vibration of its particles, the hotter the body the more rapid the vibration. Heat is measured in British Thermal Units (B. T. U.), which is the quantity of heat required to raise the temperature of a pound of pure water one degree at its point of maximum density, 39° F. The French thermal unit is the calorie and is the amount of heat required to raise one kilogram of water one degree centigrade, at corresponding temperature.

One Calorie=3.968 B. T. U.

The medical profession use the gram-calorie instead of the kilogram-calorie, and indeed mix up the systems occasionally by using the pound-calorie.

Mechanical Equivalent of Heat.

Mechanical energy and heat are mutually convertible, 778 foot-pounds being equal to one B. T. U. As one horsepower equals 33,000 foot-pounds per minute, it is equivalent to 42.42 B. T. U. per minute or 2545 per hour.

Specific Heat.

The specific heat, or capacity for heat, of any substance is the corresponding quantity of heat required to raise the temperature of unit weight of that substance one degree, compared to water as unity.

Sensible Heat.

The heat required to raise any liquid from 32° F. to its boiling point is called its sensible heat; water, for instance, has 212°—32°=180 units of sensible heat (approximately).

Latent Heat of Fusion of Ice.

As already stated, one heat unit will raise one pound of water one degree at ordinary temperatures. Yet if heat is applied to ice it is found that a very considerable quantity of heat is required to effect the melting of the ice before the temperature of the resulting water is raised even one degree; this amount is 144 B. T. U., and is called the latent heat of fusion of ice.

Latent Heat of Evaporation of Water.

Similarly if water is heated at the boiling point, 212° F., 965.7 B. T. U. is required to evaporate it, and this is called the latent heat of evaporation of water.

Starting with ice at 32° F. the heat required to evaporate it (and conversely its cooling effect) is the sum of the following:

Total Heat of Evaporation.

The latent heat of fusion of ice+the sensible heat required to raise the temperature of the water from 32° to 212°+the latent heat of evaporation, *i. e.* 144+180.9+965.7=1290.6.

With the above as a guide it is simple and

(See pages 598-9 and 607-10, Vol. II.)

easy enough to make calculations for the cooling effect due to the evaporation of water at different temperatures.

Barometric Pressure.

The atmosphere, meaning sphere of air, exists as a thin shell or layer of air encircling the earth; the inner or underside of the layer rests on the earth's surface and the outer or upper side takes the shape of an oblate spheroid. The thickness of this layer or height of the atmosphere is a matter of conjecture, but it is safe to say that 45 or 50 miles is its practical limit, and anything beyond that distance is in an extremely tenuous condition. As would be expected, the lower strata are the heaviest, and at the sea level air is at its greatest density, a cubic foot of dry air at 32° F. weighing 566.86 grains, or a little over one twelfth of a pound. Barometric pressure of the atmosphere corresponds as it were to the weight of unit volume of the air; that is to say, the barometric pressure is simply the weight of unit volume of the atmosphere, and that unit volume extends from the bottom to the top. It is expressed in terms of the weight of a column of mercury that it will support per square inch, for instance 30 inches of mercury at sea level; the barometric pressure obviously varies with the height above sea level, one inch per 1,000 feet of ascent being a rough approximation. It also varies with changes in temperature and humidity, these changes in fact being taken as indications of changes in the weather. Changes in barometric pressure considerably affect evaporation; a high barometer retards evaporation, while a low one accelerates it, and carried to an extreme all volatile liquids evaporate instantly in a vacuum. A vacuum is usually expressed in inches of mercury also, but inversely; for instance, a 26 inch vacuum would correspond to approximately a 4 inch barometer at sea level. The weight of the 30 inches of mercury, or the pressure of the atmosphere is 14.7 pounds roughly,—14.696 to be exact.

Vapor Pressure, or Elastic Force of Vapor.

As in an atmosphere of pure steam, its force at the earth's surface would be its weight; and, in a mixture of atmosphere, the elastic force or pressure of each at the surface of the earth is the weight of each; so, the barometric pressure of the atmosphere is the sum of the elastic forces of the dry atmosphere and of the vapor present in the atmosphere. At both saturation and at the dew point for any temperature, it is obvious that the elastic force of vapor is at its maximum.

Relative humidity, therefore, can be determined not only by observing the wet bulb temperature, or temperature of evaporation, but also by determining the temperature of the dew point, for, it follows that relative humidity, or the percentage of saturation for any temperature, is the ratio of the

vapor pressures at saturation and at the dew point for that temperature.

Gauge and Absolute Pressure.

And so for ordinary purposes, gauges indicating pressures start with the atmospheric pressure as the 0 point. In calculations where absolute pressures are required, for most purposes it is reckoned as gauge pressure plus 15 pounds.

When Air Behaves as a Perfect Gas.

At any percentage less than saturation air behaves as a perfect gas and obeys the laws governing gasses.

A few of these laws are pertinent to this subject:

Laws Governing Gases.

The volume of a gas diminishes as its pressure increases and vice versa; its volume and pressure are proportional to its absolute temperature.

Air expands 1-491 of its volume for each degree rise of temperature; air at 32° F. and 30 inches barometric pressure is usually taken for unit of volume.

As already stated, a cubic foot of dry air at 32° F. and 30 inches barometer weighs 566.86 grains; at any other temperature, therefore, its weight can be ascertained by dividing by its increased volume.

And, as stated elsewhere, in the psychrometric tables will be found the weight of moisture, or vapor, in a cubic foot of saturated air, and at different percentages at saturation.

The weight of the combined air and vapor is the sum of both, corrected for increase of volume due to enlargement on account of the presence of the vapor.

HUMIDITY TABLES.

It is not out of place to again emphasize the distinction that should be made in the use of the following tables:

In hygrometrical and psychrometrical readings, the dry bulb temperatures are the same, viz., the temperature of the air.

The wet bulb temperatures, however, are different, although the wet bulb temperatures indicated by both instruments are temperatures of evaporation; in the case of the hygrometer, the temperature of evaporation is that of undisturbed or stagnant air, whereas, in the case of the psychrometer, the temperature of evaporation is lower because the evaporation takes place more rapidly and with correspondingly increased cooling effect, because the wet bulb is exposed to a draft of air of approximately fifteen feet per second velocity.

And so, it will be seen that wet bulb temperatures vary all the way from hygrometric to psychrometric, depending entirely upon the velocity of the draft of air to which the wet bulb is exposed. Hence, the importance of keeping hygrometers out of air currents, and of slinging psychrometers fast enough to expose the wet bulb at the requisite velocity.

Hygrometrical Tables.

Giving Both Relative and Actual Humidity at Ordinary Temperatures Shown by the Dry Bulb for Different Depressions of the Wet Bulb.

Temperature.	1°		2°		3°		4°		5°		6°		7°		8°		9°		10°		11°		12°	
	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R	A	R	A	R.	A	R.	A.	R.	A.	R.	A.	R.	A.
60	94	5.4	88	5.1	82	4.7	76	4.4	71	4.1	66	3.8	62	3.6	58	3.3	54	3.1	50	2.9				
61	94	5.6	88	5.2	82	4.9	77	4.6	72	4.3	67	4.0	62	3.7	58	3.5	54	3.2	50	3.0	47	2.8		
62	94	5.8	88	5.4	82	5.1	77	4.7	72	4.4	67	4.1	62	3.9	58	3.6	54	3.4	50	3.1	47	2.9	44	2.7
63	94	6.0	88	5.6	82	5.2	77	4.9	72	4.6	67	4.3	63	4.0	59	3.7	55	3.5	51	3.3	47	3.0	44	2.8
64	94	6.2	88	5.8	82	5.4	77	5.1	72	4.8	67	4.5	63	4.2	59	3.9	55	3.6	51	3.4	48	3.2	45	3.0
65	94	6.4	88	6.0	83	5.6	78	5.3	73	4.9	68	4.6	63	4.3	59	4.0	55	3.8	51	3.5	48	3.3	45	3.1
66	94	6.6	88	6.2	83	5.8	78	5.5	73	5.1	68	4.8	64	4.5	60	4.2	56	3.9	52	3.7	48	3.4	45	3.2
67	94	6.8	88	6.4	83	6.0	78	5.6	73	5.3	68	5.0	64	4.7	60	4.4	56	4.1	52	3.8	49	3.6	46	3.3
68	94	7.1	88	6.6	83	6.2	78	5.8	73	5.5	68	5.2	64	4.8	60	4.5	56	4.2	52	4.0	49	3.7	46	3.5
69	94	7.3	88	6.9	83	6.5	78	6.1	73	5.7	68	5.3	64	5.0	60	4.7	56	4.4	53	4.1	50	3.9	47	3.6
70	94	7.5	88	7.1	83	6.7	78	6.3	73	5.9	69	5.5	65	5.2	61	4.9	57	4.6	53	4.3	50	4.0	47	3.8
71	94	7.8	88	7.3	83	6.9	78	6.5	73	6.1	69	5.7	65	5.4	61	5.1	57	4.7	53	4.4	50	4.2	47	3.9
72	94	8.0	89	7.6	84	7.1	79	6.7	74	6.3	69	5.9	65	5.6	61	5.3	57	5.0	54	4.7	51	4.4	48	4.1
73	94	8.3	89	7.8	84	7.4	79	7.0	74	6.6	70	6.2	66	5.8	62	5.4	58	5.1	54	4.8	51	4.5	48	4.2
74	94	8.6	89	8.1	84	7.6	79	7.2	74	6.8	70	6.4	66	6.0	62	5.6	58	5.3	55	5.0	52	4.7	48	4.4
75	94	8.9	89	8.4	84	7.9	79	7.4	74	7.0	70	6.6	66	6.2	62	5.8	58	5.5	55	5.2	52	4.9	49	4.6
76	94	9.2	89	8.6	84	8.2	79	7.7	75	7.2	71	6.8	67	6.4	63	6.1	59	5.7	55	5.4	52	5.1	49	4.8
77	94	9.5	89	8.9	84	8.4	79	8.0	75	7.5	71	7.1	67	6.7	63	6.3	59	5.9	56	5.6	53	5.3	50	4.9
78	94	9.7	89	9.2	84	8.7	79	8.2	75	7.8	71	7.3	67	6.9	63	6.5	59	6.2	56	5.8	53	5.5	50	5.1
79	95	10.1	90	9.5	85	9.0	80	8.5	75	8.0	71	7.6	67	7.2	63	6.8	59	6.4	56	6.0	53	5.6	50	5.3
80	95	10.4	90	9.8	85	9.3	80	8.8	75	8.3	71	7.8	67	7.4	63	7.0	59	6.6	56	6.2	53	5.8	50	5.5

Relative and Actual Humidity.—Humidity is stated as either relative or actual. Complete saturation of the air with moisture is stated as 100, and relative amounts by smaller percentages.

Actual humidity is the weight in grains per cubic foot of vapor in the air.

Hygrometrical Tables, Continued.

Temperature.	13°		14°		15°		16°		17°		18°		19°		20°		21°		22°		23°		24°		25°	
	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.
60																										
61																										
62																										
63																										
64																										
65																										
66																										
67																										
68																										
69																										
70																										
71																										
72	45	3.8																								
73	45	4.0	42	3.7	40	3.5	37	3.3																		
74	45	4.1	43	3.9	40	3.6	37	3.4	35	3.0	33	3.0														
75	46	4.3	43	4.0	40	3.8	38	3.6	36	3.2	33	3.1														
76	46	4.5	43	4.2	40	3.9	38	3.7	36	3.3	34	3.3														
77	47	4.6	44	4.3	41	4.1	38	3.9	36	3.4	34	3.4														
78	47	4.8	44	4.5	41	4.3	39	4.0	37	3.8	35	3.5														
79	47	5.0	44	4.7	41	4.4	39	4.2	37	3.9	35	3.7	32	3.5												
80	47	5.2	44	4.9	41	4.6	39	4.3	37	4.1	35	3.8	33	3.6												

Note.—The tables show the relative and actual humidity at ordinary temperatures, by noting the difference in the indications of the wet and dry bulb thermometers; this difference is designated the "depression of the wet bulb" and appears as the upper row of figures with degree marks attached (°). The relative humidity expressed as a percentage is catalogued under the heading "R"; the actual humidity in grains of vapor per cubic foot is catalogued under the heading "A."

Example: Dry Bulb, 80 degrees; Wet Bulb, 73 degrees; difference, or depression of the wet bulb, 7 degrees; under 7° difference and opposite 80, the temperature of the air as shown by the dry bulb, we find 67% relative humidity and 7.4 grs. actual humidity.

Hygrometrical Tables, Continued

Temperature.	1°		2°		3°		4°		5°		6°		7°		8°		9°		10°		11°		12°	
	R.	A.	R.	A.	R.	A.	R.	A.	R	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.
81	95	10.7	90	10.1	85	9.5	80	9.1	76	8.6	72	8.1	68	7.6	64	7.2	60	6.8	56	6.4	53	6.0	50	5.7
82	95	11.1	90	10.5	85	9.9	80	9.4	76	8.9	72	8.4	68	7.9	64	7.5	60	7.1	57	6.7	54	6.3	51	5.9
83	95	11.7	90	10.8	85	10.2	80	9.7	76	9.1	72	8.6	68	8.2	64	7.7	60	7.3	57	6.9	54	6.5	51	6.1
84	95	11.7	90	11.1	85	10.5	80	10.0	76	9.4	72	8.9	68	8.5	64	8.0	60	7.5	57	7.1	54	6.7	51	6.3
85	95	12.1	90	11.5	85	10.9	80	10.3	76	9.7	72	9.2	68	8.7	64	8.3	61	7.8	58	7.4	55	7.0	52	6.6
86	95	12.5	90	11.8	85	11.2	80	10.6	76	10.1	72	9.5	68	9.0	64	8.5	61	8.1	58	7.6	55	7.2	52	6.8
87	95	12.9	90	12.2	85	11.6	81	11.0	77	10.4	73	9.8	69	9.3	65	8.8	61	8.3	58	7.9	55	7.4	52	7.0
88	95	13.3	90	12.6	85	12.0	81	11.4	77	10.8	73	10.2	69	9.6	65	9.1	61	8.6	58	8.1	55	7.7	52	7.3
89	95	13.7	90	13.0	85	12.3	81	11.7	77	11.1	73	10.5	69	10.0	65	9.4	61	8.9	58	8.4	55	8.0	52	7.5
90	95	14.1	90	13.4	85	12.7	81	12.1	77	11.4	73	10.8	69	10.3	65	9.7	62	9.2	59	8.7	56	8.3	53	7.8
91	95	14.5	90	13.8	86	13.1	82	12.5	78	11.8	74	11.2	70	10.6	66	10.1	62	9.5	59	9.0	56	8.5	53	8.1
92	95	14.9	90	14.2	86	13.5	82	12.8	78	12.2	74	11.6	70	11.0	66	10.4	62	9.9	59	9.3	56	8.8	53	8.3
93	95	15.4	90	14.7	86	14.0	82	13.3	78	12.6	74	11.9	70	11.3	66	10.7	63	10.2	60	9.6	57	9.1	54	8.7
94	95	15.9	90	15.1	86	14.4	82	13.7	78	13.0	74	12.3	70	11.7	66	11.1	63	10.5	60	10.0	57	9.5	54	9.0
95	95	16.3	90	15.5	86	14.8	82	14.1	78	13.4	74	12.7	70	12.1	66	11.5	63	10.9	60	10.3	57	9.8	54	9.3
96	95	16.8	90	16.0	86	15.2	82	14.5	78	13.8	74	13.1	70	12.4	66	11.8	63	11.2	60	10.7	57	10.1	54	9.6
97	95	17.3	90	16.5	86	15.7	82	14.9	78	14.2	74	13.5	70	12.8	67	12.2	64	11.6	60	11.0	57	10.4	54	9.9
98	95	17.8	90	17.0	86	16.2	82	15.4	78	14.6	74	13.9	70	13.2	67	12.6	64	12.0	61	11.4	58	10.8	55	10.2
99	95	18.4	90	17.5	86	16.7	82	15.9	78	15.1	74	14.4	71	13.7	67	13.0	64	12.3	61	11.7	58	11.1	55	10.5
100	95	18.9	90	18.0	86	17.2	82	16.3	78	15.5	74	14.8	71	14.1	68	13.4	64	12.7	61	12.1	58	11.5	55	10.9

Hygrometer Precautions.—Hygrometers should be placed free from air currents and kept amply supplied with soft water (distilled if possible). Change muslin and wick often and see that the wet bulb is constantly moist and free from discolorations.

Hygrometrical Tables, Concluded.

Temperature.	13°		14°		15°		16°		17°		18°		19°		20°		21°		22°		23°		24°	
	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A
81	47	5.4	44	5.1	41	4.8	39	4.5	37	4.2	35	4.0	33	3.7										
82	48	5.6	45	5.2	42	4.9	40	4.7	38	4.4	35	4.1	33	3.9	31	3.6								
83	48	5.8	45	5.4	42	5.1	40	4.8	38	4.6	36	4.3	34	4.0	32	3.8	30	3.6						
84	48	6.0	45	5.6	43	5.3	40	5.0	38	4.7	36	4.5	34	4.2	32	4.0	30	3.7	28	3.5				
85	49	6.2	46	5.9	43	5.5	40	5.2	38	4.9	36	4.6	34	4.3	32	4.1	30	3.8	28	3.6				
86	49	6.4	46	6.1	43	5.7	40	5.4	38	5.1	36	4.8	34	4.5	32	4.2	30	4.0	28	3.7	27	3.5		
87	49	6.6	46	6.3	43	5.9	41	5.6	39	5.3	37	5.0	35	4.7	33	4.4	31	4.2	29	3.9	27	3.7		
88	49	6.9	46	6.5	43	6.1	41	5.8	39	5.5	37	5.2	35	4.9	33	4.6	31	4.3	29	4.1	27	3.8		
89	49	7.1	46	6.7	43	6.4	41	6.0	39	5.7	37	5.4	35	5.1	33	4.8	31	4.5	29	4.2	28	4.0		
90	50	7.4	47	7.0	44	6.6	42	6.2	40	5.9	38	5.6	36	5.3	34	5.0	32	4.7	30	4.4	28	4.2		
91	50	7.7	47	7.2	44	6.8	42	6.5	40	6.1	38	5.8	36	5.5	34	5.1	32	4.8	30	4.5	28	4.3		
92	50	7.9	47	7.5	45	7.1	43	6.7	41	6.3	38	6.0	36	5.7	34	5.3	32	5.0	30	4.8	28	4.5		
93	51	8.2	48	7.8	45	7.4	43	6.9	41	6.6	38	6.2	36	5.9	34	5.5	32	5.2	30	5.0	29	4.7		
94	51	8.5	48	8.0	45	7.6	43	7.2	41	6.8	39	6.4	37	6.1	35	5.7	33	5.4	31	5.1	29	4.9		
95	51	8.8	48	8.3	45	7.9	43	7.5	41	7.1	39	6.7	37	6.3	35	6.0	33	5.6	31	5.3	30	5.0		
96	52	9.1	49	8.6	46	8.2	43	7.7	41	7.3	39	6.9	37	6.5	35	6.2	33	5.9	31	5.6	30	5.3		
97	52	9.4	49	8.9	46	8.4	44	8.0	42	7.6	39	7.2	37	6.8	35	6.4	33	6.1	31	5.8	30	5.5		
98	52	9.7	49	9.2	46	8.7	44	8.3	42	7.8	40	7.4	38	7.1	36	6.7	34	6.3	32	6.0	30	5.7		
99	52	10.0	49	9.5	46	9.0	44	8.6	42	8.1	40	7.7	38	7.3	36	6.9	34	6.6	32	6.2	30	5.9		
100	52	10.4	49	9.9	47	9.4	45	8.9	43	8.4	40	8.0	38	7.6	36	7.2	34	6.8	32	6.4	30	6.1	29	5.8

Note.—The tables show the relative and actual humidity at ordinary temperatures by noting the difference in the indications of the wet and dry bulb thermometers; this difference is designated the "depression of the wet bulb" and appears as the upper row of figures with degree marks attached (°). The relative humidity expressed as a percentage is catalogued under the heading "R"; the actual humidity in grains of vapor per cubic foot is catalogue under the heading "A."

Example: Dry Bulb 80 degrees; Wet Bulb 73 degrees; difference, or depression of the wet bulb, 7 degrees; under 7° differene and opposite 80, the temperature of the air as shown by the dry bulb, we find 67% relative humidity and 7.4 grs. actual humidity.

U. S. W. B. Psychrometric Tables.

(United States Weather Bureau)

Dry Bulb 0° (0.48)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
1	— 7	67	.32
2	—20	33	.16
—3	—66	1	.01

Dry Bulb 1° (0.51)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
0	— 6	68	.35
—1	—17	36	.19
—2	—50	5	.03

Dry Bulb 2° (0.53)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
1	— 5	70	.37
0	—15	39	.21
—1	—40	9	.05

Dry Bulb 3° (0.55)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
2	— 4	71	.40
1	—13	42	.23
0	—32	13	.07

Dry Bulb 4° (0.58)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
3	— 2	72	.42
2	—11	44	.26
1	—28	17	.10

Dry Bulb 5° (0.61)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
4	— 1	73	.45
3	— 9	46	.28
2	—24	20	.12

Dry Bulb 6° (0.64)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
5	0	74	.47
4	— 8	49	.31
3	—21	23	.15
2	———	1	.01

Dry Bulb 7° (0.67)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
6	+ 1	75	.50
5	— 6	51	.34
4	—18	26	.18
3	—58	2	.01

Dry Bulb 8° (0.70)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
7	+ 3	76	.53
6	— 5	53	.37
5	—15	29	.20
4	—42	6	.04

Dry Bulb 9° (0.74)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
8	+ 4	77	.57
7	— 3	55	.41
6	—13	32	.24
5	—33	10	.07

Dry Bulb 10° (0.78)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
9	+ 5	78	.61
8	— 2	56	.44
7	—10	34	.27
6	—27	13	.10

Dry Bulb 11° (0.82)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
10	+ 6	79	.64
9	0	58	.48
8	— 8	37	.30
7	—22	16	.13

Dry Bulb 12° (0.86)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
11	+ 7	80	.69
10	+ 2	59	.51
9	— 6	39	.34
8	—19	19	.16
7	———	0	.01

Dry Bulb 13° (0.90)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
12	+ 9	80	.72
11	+ 3	61	.55
10	— 4	41	.37
9	—15	23	.21
8	—46	4	.04

Dry Bulb 14° (0.94)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
13	+10	81	.76
12	+ 5	62	.58
11	— 2	44	.41
10	—12	26	.24
9	—33	8	.08

Dry Bulb 15° (0.99)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
14	+11	82	.81
13	+ 6	64	.63
12	0	46	.46
11	— 9	29	.29
10	—26	11	.10

Dry Bulb 16° (1.03)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
15	+12	82	.84
14	+ 7	65	.67
13	+ 1	48	.49
12	— 7	31	.32
11	—20	14	.15

Dry Bulb 17° (1.08)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
16	+13	83	.90
15	+ 9	66	.71
14	+ 3	50	.54
13	— 4	34	.37
12	—16	17	.18

Dry Bulb 18° (1.13)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
17	+14	84	.95
16	+10	68	.77
15	+ 5	52	.59
14	— 2	36	.41
13	—13	20	.23
12	—37	5	.06

Dry Bulb 19° (1.18)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
18	+15	84	.99
17	+11	69	.81
16	+ 6	53	.63
15	0	38	.45
14	—10	23	.27
13	—27	8	.09

Dry Bulb 20° (1.24)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
19	+16	85	1.05
18	+12	70	.87
17	+ 8	55	.68
16	+ 2	40	.49
15	— 7	26	.32
14	—21	12	.15

Dry Bulb 21° (1.29)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
20	+18	85	1.10
19	+14	71	.92
18	+ 9	56	.72
17	+ 3	42	.54
16	— 4	28	.36
15	—16	15	.19

Dry Bulb 22° (1.36)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
21	+19	86	1.17
20	+15	71	.97
19	+11	58	.79
18	+ 5	44	.60
17	— 2	31	.42
16	—12	17	.23

Dry Bulb 23° (1.42)

Wet Bulb °F	Dew Point °F	Rel. Hum. %	Act. Hum. Grs.
22	+20	86	1.22
21	+16	72	1.02
20	+12	59	.84
19	+ 7	46	.65
18	0	33	.47
17	— 9	20	.28

Note.—The figures in parenthesis following the dry bulb temperatures show the actual humidity at 100% relative humidity, or saturation.

U. S. W. B. Psychrometric Tables, Continued.

Dry Bulb 24° (1.48)			
Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
°F	°F	%	Grs.
23	21	87	1.29
22	17	73	1.08
21	13	60	.89
20	9	47	.70
19	2	35	.52
18	— 6	22	.32
17	—20	10	.15

Dry Bulb 25° (1.55)			
Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
°F	°F	%	Grs.
24	22	87	1.35
23	19	74	1.15
22	15	62	.96
21	10	49	.76
20	5	37	.57
19	— 3	25	.39
18	—15	13	.20

Dry Bulb 26° (1.62)			
Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
°F	°F	%	Grs.
25	23	87	1.41
24	20	75	1.21
23	16	63	1.02
22	12	51	.83
21	7	39	.63
20	— 1	27	.44
19	11	16	.26

Dry Bulb 27° (1.70)			
26	24	88	1.50
25	21	76	1.30
24	18	64	1.09
23	13	52	.88
22	8	41	.70
21	2	29	.49
20	—7	18	.31

Dry Bulb 28° (1.77)			
27	25	88	1.56
26	22	76	1.35
25	19	65	1.15
24	15	54	.96
23	10	43	.76
22	4	32	.57
21	—4	21	.37

Dry Bulb 29° (1.85)			
28	26	88	1.63
27	23	77	1.42
26	20	66	1.22
25	16	55	1.02
24	12	44	.81
23	6	34	.63
22	—1	23	.43

Dry Bulb 30° (1.94)			
29	27	89	1.73
28	25	78	1.51
27	21	67	1.30
26	18	56	1.09
25	14	46	.89
24	8	36	.70
23	2	26	.50
22	— 7	16	.31
21	—25	6	.12

Dry Bulb 31° (2.02)			
30	28	89	1.80
29	26	78	1.58
28	23	68	1.37
27	19	58	1.17
26	15	47	.95
25	10	37	.75
24	4	28	.57
23	— 4	18	.37
22	—18	8	.16

Dry Bulb 32° (2.11)			
31	30	89	1.88
30	27	79	1.67
29	24	69	1.46
28	21	59	1.24
27	17	49	1.03
26	12	39	.82
25	7	30	.63
24	— 1	20	42
23	—12	11	.23

Dry Bulb 33° (2.19)			
32	31	90	1.97
31	28	80	1.75
30	25	70	1.54
29	22	60	1.31
28	18	51	1.11
27	14	41	.90
26	9	32	.70
25	2	23	.51
24	— 7	14	.31
23	—26	5	.11

Dry Bulb 34° (2.28)			
33	32	90	2.05
32	29	81	1.85
31	26	71	1.62
30	23	62	1.42
29	20	52	1.19
28	16	43	.98
27	11	34	.77
26	5	25	.57
25	— 3	16	.36
24	—17	8	.18

Dry Bulb 35° (2.37)			
34	33	91	2.16
33	30	81	1.92
32	28	72	1.71
31	25	63	1.49
30	21	54	1.28
29	17	45	1.07
28	13	36	.85
27	7	27	.64
26	0	19	45
25	11	10	.23

Dry Bulb 36° (2.46)			
35	34	91	2.24
34	31	82	2.02
33	29	73	1.79
32	26	64	1.57
31	23	55	1.35
30	19	46	1.13
29	15	38	.94
28	10	29	.71
27	3	21	.52
26	— 6	13	.32
25	—25	5	.12

Dry Bulb 37° (2.55)			
36	35	91	2.32
35	32	83	2.12
34	30	74	1.89
33	27	65	1.66
32	24	57	1.41
31	21	48	1.22
30	17	40	1.02
29	12	31	.79
28	6	23	.59
27	3	15	.38
26	16	7	.18

Dry Bulb 38° (2.65)			
37	36	91	2.41
36	33	83	2.20
35	31	75	1.99
34	28	66	1.75
33	25	58	1.53
32	22	50	1.32
31	18	42	1.11
30	14	33	.88
29	8	25	.66
28	1	17	.45
27	10	10	.27

Relative and Actual Humidity.—Humidity is stated as either relative or actual. Complete saturation of the air with moisture is stated as 100, and relative amounts by smaller percentages.

Actual humidity is the weight in grains per cubic foot of vapor in the air.

U, S. W. B. Psychrometric Tables, Continued.

Dry Bulb 39° (2.75)

Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
°F	°F	%	Grs.
38	37	92	2.53
37	34	83	2.28
36	32	75	2.06
35	29	67	1.84
34	27	59	1.62
33	23	51	1.40
32	20	43	1.18
31	16	35	.96
30	11	27	.74
29	4	20	.55
28	—5	12	.33

Dry Bulb 40° (2.85)

Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
°F	°F	%	Grs.
39	38	92	2.62
38	35	83	2.37
37	33	75	2.14
36	30	68	1.94
35	28	60	1.71
34	25	52	1.48
33	21	45	1.28
32	18	37	1.05
31	13	29	.83
30	7	22	.63
29	—1	15	.43

Dry Bulb 41° (2.96)

Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
°F	°F	%	Grs.
40	39	92	2.72
39	36	84	2.49
38	34	76	2.25
37	31	69	2.04
36	29	61	1.81
35	26	54	1.60
34	23	46	1.36
33	19	39	1.16
32	15	31	.92
31	10	24	.71
30	2	17	.50

Dry Bulb 42° (3.06)

Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
41	40	92	2.82
40	38	85	2.60
39	35	77	2.36
38	33	69	2.11
37	30	62	1.90
36	27	55	1.68
35	24	47	1.44
34	21	40	1.22
33	17	33	1.01
32	12	26	.80
31	6	19	.58
30	—3	12	.37

Dry Bulb 43° (3.18)

Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
42	41	92	2.93
41	39	85	2.70
40	36	77	2.45
39	34	70	2.23
38	31	63	2.00
37	28	55	1.75
36	25	48	1.53
35	22	42	1.34
34	19	35	1.11
33	14	28	.89
32	9	21	.67
31	1	14	.45

Dry Bulb 44° (3.29)

Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
43	42	93	3.06
42	40	85	2.80
41	37	78	2.57
40	35	71	2.34
39	32	63	2.07
38	30	56	1.84
37	27	49	1.61
36	24	43	1.41
35	20	36	1.18
34	16	30	.99
33	11	23	.76
32	4	16	.53

Dry Bulb 45° (3.41)

Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
44	43	93	3.17
43	41	86	2.93
42	38	78	2.66
41	36	71	2.42
40	34	64	2.18
39	31	57	1.94
38	28	51	1.74
37	25	44	1.50
36	22	38	1.30
35	18	31	1.06
34	13	25	.85
33	7	18	.61
32	—1	12	.41

Dry Bulb 46° (3.54)

Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
45	44	93	3.29
44	42	86	3.04
43	40	79	2.80
42	37	72	2.55
41	35	65	2.30
40	32	58	2.05
39	29	52	1.84
38	27	45	1.59
37	23	39	1.38
36	20	32	1.13
35	15	26	.92
34	10	20	.71
33	3	14	.50

Dry Bulb 47° (3.67)

Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
46	45	93	3.41
45	43	86	3.16
44	41	79	2.90
43	38	72	2.64
42	36	66	2.42
41	33	59	2.17
40	31	53	1.95
39	28	46	1.69
38	25	40	1.47
37	21	34	1.25
36	17	28	1.03
35	12	22	.81
34	6	16	.59

Dry Bulb 48° (3.80)

Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
47	46	93	3.53
46	44	86	3.27
45	42	79	3.00
44	40	73	2.77
43	37	66	2.51
42	35	60	2.28
41	32	54	2.05
40	29	47	1.79
39	26	41	1.56
38	23	35	1.33
37	19	29	1.10
36	14	23	.88
35	9	18	.68
34	1	12	.46
33	—10	7	.27

Dry Bulb 49° (3.94)

Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
48	47	93	3.66
47	45	86	3.39
46	43	80	3.15
45	41	73	2.88
44	38	67	2.64
43	36	61	2.40
42	33	54	2.13
41	30	48	1.89
40	28	42	1.66
39	24	36	1.42
38	21	31	1.22
37	16	25	.99
36	11	19	.75
35	5	14	.55
34	—5	9	.35

Dry Bulb 50° (4.08)

Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
49	48	93	3.80
48	46	87	3.55
47	44	80	3.26
46	42	74	3.02
45	40	67	2.73
44	37	61	2.49
43	34	55	2.24
42	32	49	2.00
41	29	43	1.76
40	26	38	1.55
39	22	32	1.31
38	18	27	1.10
37	13	21	.86
36	8	16	.65
35	0	10	.41

U. S. W. B. Psychrometric Tables, Continued.

Dry Bulb 51° (4.22)				Dry Bulb 52° (4.37)				Dry Bulb 53° (4.53)			
Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
°F	°F	%	Grs.	°F	°F	%	Grs.	°F	°F	%	Grs.
50	49	94	3.97	51	50	94	4.11	52	51	94	4.26
49	47	87	3.67	50	48	87	3.80	51	49	87	3.94
48	45	81	3.42	49	46	81	3.54	50	47	81	3.67
47	43	75	3.16	48	44	75	3.28	49	45	75	3.40
46	41	68	2.87	47	42	69	3.02	48	43	69	3.13
45	38	62	2.62	46	40	63	2.75	47	41	63	2.85
44	36	56	2.36	45	37	57	2.49	46	38	58	2.63
43	33	50	2.11	44	34	51	2.23	45	36	52	2.36
42	30	45	1.90	43	32	46	2.01	44	33	47	2.13
41	27	39	1.65	42	29	40	1.75	43	30	41	1.86
40	24	34	1.43	41	26	35	1.53	42	27	36	1.63
39	20	28	1.18	40	22	29	1.27	41	24	31	1.41
38	16	23	.97	39	18	24	1.05	40	20	26	1.18
37	10	17	.72	38	13	19	.83	39	15	20	.91
36	3	12	.51	37	7	14	.61	38	10	16	.73

Dry Bulb 54° (4.69)				Dry Bulb 55° (4.85)				Dry Bulb 56° (5.02)			
53	52	94	4.41	54	53	94	4.56	55	54	94	4.72
52	50	88	4.13	53	51	88	4.27	54	53	88	4.42
51	48	82	3.85	52	50	82	3.96	53	51	82	4.12
50	46	76	3.56	51	48	76	3.69	52	49	76	3.82
49	44	70	3.28	50	45	70	3.40	51	47	71	3.56
48	42	64	3.00	49	43	65	3.15	50	44	65	3.26
47	40	59	2.77	48	41	59	2.86	49	42	60	3.01
46	37	53	2.49	47	38	54	2.62	48	40	55	2.77
45	34	48	2.25	46	36	49	2.38	47	37	50	2.51
44	32	42	1.97	45	33	43	2.09	46	34	44	2.21
43	29	37	1.74	44	30	38	1.84	45	32	39	1.96
42	25	32	1.50	43	27	33	1.60	44	29	34	1.71
41	22	27	1.27	42	24	28	1.36	43	25	30	1.51
40	18	22	1.03	41	20	23	1.12	42	22	25	1.26
39	12	17	.80	40	15	19	.92	41	17	20	1.00
38	6	12	.56	39	9	14	.68	40	12	16	.80
37	—4	8	.38	38	1	9	.44	39	5	11	.55

Dry Bulb 57° (5.19)				Dry Bulb 58° (5.37)				Dry Bulb 59° (5.56)			
56	55	94	4.88	57	56	94	5.05	58	57	94	5.23
55	54	88	4.57	56	55	88	4.73	57	56	89	4.95
54	52	82	4.26	55	53	83	4.46	56	54	83	4.61
53	50	77	4.00	54	51	77	4.13	55	52	78	4.34
52	48	71	3.68	53	49	72	3.87	54	50	72	4.00
51	46	66	3.43	52	47	66	3.54	53	48	67	3.73
50	43	61	3.17	51	45	61	3.28	52	46	62	3.45
49	41	55	2.85	50	42	56	3.01	51	44	57	3.17
48	39	50	2.59	49	40	51	2.74	50	41	52	2.89
47	36	45	2.33	48	37	46	2.47	49	39	47	2.61
46	33	40	2.08	47	35	41	2.20	48	36	42	2.34
45	30	35	1.82	46	32	37	1.99	47	33	38	2.11
44	27	31	1.61	45	29	32	1.72	46	30	33	1.83
43	24	26	1.35	44	25	27	1.45	45	27	29	1.61
42	19	22	1.14	43	21	23	1.24	44	23	24	1.34
41	14	17	.88	42	17	18	.97	43	19	20	1.11
40	9	13	.67	41	11	14	.75	42	14	16	.89
39	0	8	.42	40	4	10	.54	41	8	11	.61
38	—14	4	.20	39	—6	6	.32	40	—1	7	.39
37	——	——	——	38	—30	1	.05	39	—16	3	.17

U. S. W. B. Psychrometric Tables, Continued.

Dry Bulb 60° (5.75)				Dry Bulb 61° (5.94)				Dry Bulb 62° (6.14)			
Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
°F	°F	%	Grs.	°F	°F	%	Grs.	°F	°F	%	Grs.
59	58	94	5.40	60	59	94	5.58	61	60	94	5.77
58	57	89	5.12	59	58	89	5.29	60	59	89	5.46
57	55	83	4.77	58	56	84	4.99	59	57	84	5.16
56	53	78	4.48	57	54	78	4.63	58	55	79	4.85
55	51	73	4.20	56	52	73	4.34	57	53	74	4.54
54	49	68	3.91	55	50	68	4.04	56	52	69	4.24
53	47	63	3.62	54	48	63	3.74	55	50	64	3.93
52	45	58	3.34	53	46	58	3.45	54	47	59	3.63
51	43	53	3.05	52	44	54	3.21	53	45	54	3.32
50	40	48	2.76	51	42	49	2.91	52	43	50	3.07
49	38	43	2.47	50	39	44	2.61	51	40	45	2.77
48	35	39	2.24	49	36	40	2.37	50	38	41	2.52
47	32	34	1.96	48	33	35	2.08	49	35	36	2.21
46	29	30	1.73	47	30	31	1.84	48	32	32	1.96
45	25	26	1.49	46	27	27	1.60	47	29	28	1.72
44	21	21	1.21	45	23	22	1.31	46	25	24	1.47
43	17	17	.98	44	19	18	1.07	45	21	20	1.23
42	11	13	.75	43	14	14	.83	44	16	16	.98
41	4	9	.52	42	8	10	.60	43	11	12	.74
40	− 8	5	.29	41	2	7	.42	42	3	8	.49
39	−36	1	.06	40	−18	3	.18	41	− 9	4	.25
38	——	0	——	39	——	1	.06	40	−45	1	.06

Dry Bulb 63° (6.35)				Dry Bulb 64° (6.56)				Dry Bulb 65° (6.78)			
62	61	95	6.03	63	62	95	6.21	64	63	95	6.44
61	60	89	5.65	62	61	90	5.90	63	62	90	6.10
60	58	84	5.33	61	59	84	5.51	62	60	85	5.76
59	56	79	5.02	60	57	79	5.18	61	59	80	5.42
58	55	74	4.70	59	56	74	4.85	60	57	75	5.08
57	53	69	4.38	58	54	70	4.59	59	55	70	4.75
56	51	64	4.06	57	52	65	4.26	58	53	66	4.47
55	49	60	3.81	56	50	60	3.94	57	51	61	4.14
54	47	55	3.49	55	48	56	3.67	56	49	56	3.80
53	44	50	3.17	54	46	51	3.35	55	47	52	3.53
52	42	46	2.92	53	43	47	3.08	54	45	48	3.25
51	39	42	2.67	52	41	43	2.82	53	42	44	2.98
50	36	37	2.35	51	38	38	2.49	52	40	39	2.64
49	34	33	2.10	50	35	34	2.23	51	37	35	2.37
48	30	29	1.84	49	32	30	1.97	50	34	31	2.10
47	27	25	1.59	48	29	26	1.71	49	31	27	1.83
46	23	21	1.34	47	25	22	1.44	48	27	24	1.63
45	19	17	1.08	46	21	18	1.18	47	24	20	1.36
44	14	13	.83	45	17	15	.98	46	19	16	1.08
43	7	10	.64	44	11	11	.72	45	14	12	.81
42	− 2	6	.38	43	3	7	.46	44	7	9	.61
41	−20	2	.13	42	−10	4	.26	43	− 3	5	.34
40	——	——	——	41	——	0	0	42	−22	2	.14

U. S. W. B. Psychrometric Tables, Continued.

Dry Bulb 66° (7.01)				Dry Bulb 67° (7.24)				Dry Bulb 68° (7.48)			
Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
°F	°F	%	Grs.	°F	°F	%	Grs.	°F	°F	%	Grs.
65	64	95	6.66	66	66	95	6.88	67	67	95	7.11
64	63	90	6.31	65	64	90	6.52	66	65	90	6.73
63	61	85	5.96	64	62	85	6.15	65	63	85	6.36
62	60	80	5.61	63	61	80	5.79	64	62	80	5.98
61	58	75	5.26	62	59	75	5.43	63	60	76	5.68
60	56	71	4.98	61	57	71	5.14	62	58	71	5.31
59	54	66	4.63	60	55	66	4.78	61	57	67	5.01
58	52	61	4.28	59	53	62	4.49	60	55	62	4.64
57	50	57	4.00	58	52	58	4.20	59	53	58	4.34
56	48	53	3.72	57	49	53	3.84	58	51	54	4.04
55	46	48	3.36	56	47	49	3.55	57	49	50	3.74
54	44	44	3.08	55	45	45	3.26	56	46	46	3.44
53	41	40	2.80	54	43	41	2.97	55	44	42	3.14
52	38	36	2.52	53	40	37	2.68	54	42	38	2.84
51	35	32	2.24	52	37	33	2.39	53	39	34	2.54
50	32	29	2.03	51	34	30	2.17	52	36	31	2.32
49	29	25	1.75	50	31	26	1.88	51	33	27	2.02
48	26	21	1.47	49	28	22	1.59	50	29	23	1.72
47	22	17	1.19	48	24	19	1.38	49	26	20	1.50
46	17	14	.98	47	19	15	1.09	48	22	16	1.20
45	11	10	.70	46	14	12	.87	47	17	13	.98
44	2	7	.49	45	7	8	.58	46	11	10	.75
43	—11	3	.21	44	— 3	5	.36	45	2	6	.45
42	——	0	——	43	—23	2	.15	44	—11	3	.23

Dry Bulb 69° (7.73)				Dry Bulb 70° (7.98)				Dry Bulb 71° (8.24)			
68	68	95	7.34	69	69	95	7.58	70	70	95	7.83
67	66	90	6.96	68	67	90	7.18	69	68	90	7.42
66	64	85	6.57	67	65	86	6.86	68	67	86	7.09
65	63	81	6.26	66	64	81	6.46	67	65	81	6.67
64	61	76	5.87	65	62	77	6.15	66	63	77	6.35
63	59	72	5.57	64	61	72	5.75	65	62	72	5.93
62	58	67	5.18	63	59	68	5.43	64	60	68	5.60
61	56	63	4.87	62	57	64	5.11	63	58	64	5.27
60	54	59	4.56	61	55	59	4.71	62	56	60	4.94
59	52	55	4.25	60	53	55	4.39	61	54	56	4.61
58	50	51	3.94	59	51	51	4.07	60	52	52	4.28
57	48	47	3.63	58	49	48	3.83	59	50	48	3.95
56	45	43	3.32	57	47	44	3.51	58	48	45	3.71
55	43	39	3.01	56	44	40	3.19	57	46	41	3.38
54	40	35	2.71	55	42	36	2.87	56	43	37	3.05
53	37	32	2.47	54	39	33	2.63	55	41	33	2.72
52	34	28	2.16	53	36	29	2.31	54	38	30	2.47
51	31	24	1.86	52	33	25	1.99	53	35	27	2.22
50	28	21	1.62	51	30	22	1.76	52	31	23	1.90
49	24	18	1.39	50	26	19	1.52	51	28	20	1.65
48	19	14	1.08	49	22	15	1.20	50	24	17	1.40
47	14	11	.85	48	17	12	.96	49	20	13	1.07
46	7	8	.62	47	11	9	.72	48	14	10	.82
45	— 3	5	.39	46	2	6	.48	47	7	7	.58
44	—24	1	.08	45	—11	3	.24	46	— 3	4	.33

U. S. W. B. Psychrometric Tables, Continued.

Dry Bulb 72° (8.51)				Dry Bulb 73° (8.78)				Dry Bulb 74° (9.07)			
Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
°F	°F	%	Grs.	°F	°F	%	Grs.	°F	°F	%	Grs.
71	71	95	8.09	72	72	95	8.34	73	73	95	8.62
70	69	91	7.74	71	70	91	7.99	72	71	91	8.25
69	68	86	7.32	70	69	86	7.55	71	70	86	7.80
68	66	82	6.98	69	67	82	7.20	70	68	82	7.44
67	64	77	6.56	68	66	78	6.85	69	67	78	7.07
66	63	73	6.21	67	64	73	6.41	68	65	74	6.71
65	61	69	5.87	66	62	69	6.06	67	63	69	6.26
64	59	65	5.53	65	60	65	5.71	66	62	65	5.90
63	58	61	5.19	64	59	61	5.35	65	60	61	5.53
62	56	57	4.85	63	57	57	5.00	64	58	58	5.20
61	54	53	4.51	62	55	53	4.65	63	56	54	4.90
60	52	49	4.17	61	53	50	4.39	62	54	50	4.54
59	50	45	3.81	60	51	46	4.04	61	52	47	4.26
58	47	42	3.57	59	49	42	3.69	60	50	43	3.90
57	45	38	3.23	58	46	39	3.42	59	48	39	3.54
56	42	34	2.89	57	44	35	3.07	58	45	36	3.27
55	40	31	2.64	56	41	32	2.81	57	43	33	2.99
54	37	28	2.38	55	38	29	2.55	56	40	29	2.63
53	33	24	2.04	54	35	25	2.19	55	37	26	2.36
52	30	21	1.79	53	32	22	1.93	54	34	23	2.09
51	26	18	1.53	52	28	19	1.67	53	30	20	1.82
50	22	15	1.28	51	25	16	1.40	52	27	17	1.54
49	17	12	1.02	50	20	13	1.14	51	23	14	1.27
48	11	9	.77	49	15	10	.88	50	18	11	1.00
47	3	6	.51	48	8	7	.62	49	12	8	.73
46	—11	3	.26	47	— 3	4	.35	48	3	5	.45
Dry Bulb 75° (9.36)				**Dry Bulb 76° (9.66)**				**Dry Bulb 77° (9.96)**			
74	74	96	8.99	75	75	96	9.27	76	76	96	9.56
73	72	91	8.52	74	73	91	8.79	75	74	91	9.06
72	71	86	8.05	73	72	87	8.40	74	73	87	8.67
71	69	82	7.68	72	70	82	7.92	73	71	83	8.27
70	68	78	7.30	71	69	78	7.54	72	70	79	7.87
69	66	74	6.93	70	67	74	7.15	71	68	74	7.37
68	64	70	6.55	69	66	70	6.76	70	67	71	7.07
67	63	66	6.18	68	64	66	6.38	69	65	67	6.67
66	61	62	5.80	67	62	62	5.99	68	63	63	6.28
65	59	58	5.43	66	60	59	5.70	67	62	59	5.88
64	57	54	5.05	65	59	55	5.31	66	60	56	5.58
63	55	51	4.77	64	57	51	4.93	65	58	52	5.18
62	54	47	4.40	63	55	48	4.64	64	56	48	4.78
61	51	44	4.12	62	53	44	4.25	63	54	45	4.48
60	49	40	3.74	61	51	41	3.96	62	52	42	4.18
59	47	37	3.46	60	48	38	3.67	61	50	39	3.88
58	44	34	3.18	59	46	34	3.28	60	48	35	3.49
57	42	30	2.81	58	43	31	2.99	59	45	32	3.19
56	39	27	2.53	57	41	28	2.70	58	42	29	2.89
55	36	24	2.25	56	38	25	2.42	57	39	26	2.59
54	32	21	1.97	55	34	22	2.13	56	36	23	2.29
53	29	18	1.68	54	31	19	1.84	55	33	20	1.99
52	25	15	1.40	53	27	16	1.55	54	29	17	1.69
51	21	12	1.12	52	23	13	1.26	53	26	14	1.39
50	15	9	.84	51	18	11	1.06	52	21	12	1.20
49	8	7	.65	50	12	8	.77	51	16	9	.90
48	— 2	4	.37	49	4	5	.48	50	9	6	.60

U. S. W. B. Psychrometric Tables, Continued.

Dry Bulb 78° (10.28)				Dry Bulb 79° (10.60)				Dry Bulb 80° (10.93)			
Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
°F	°F	%	Grs.	°F	°F	%	Grs.	°F	°F	%	Grs.
77	77	96	9.87	78	78	96	10.18	79	79	96	10.49
76	75	91	9.36	77	76	91	9.65	78	77	91	9.95
75	74	87	8.94	76	75	87	9.22	77	76	87	9.51
74	72	83	8.53	75	73	83	8.80	76	74	83	9.07
73	71	79	8.12	74	72	79	8.38	75	73	79	8.64
72	69	75	7.71	73	70	75	7.95	74	72	75	8.20
71	68	71	7.30	72	69	71	7.53	73	70	72	7.87
70	66	67	6.89	71	67	68	7.21	72	68	68	7.43
69	64	63	6.48	70	66	64	6.79	71	67	64	7.00
68	63	60	6.17	69	64	60	6.36	70	65	61	6.67
67	61	56	5.76	68	62	57	6.04	69	63	57	6.23
66	59	53	5.45	67	60	53	5.62	68	62	54	5.90
65	57	49	5.04	66	59	50	5.30	67	60	50	5.47
64	55	46	4.73	65	57	46	4.88	66	58	47	5.14
63	53	43	4.42	64	55	43	4.56	65	56	44	4.82
62	51	39	4.01	63	53	40	4.24	64	54	41	4.48
61	49	36	3.70	62	50	37	3.92	63	52	38	4.14
60	46	33	3.39	61	48	34	3.60	62	50	35	3.82
59	44	30	3.08	60	46	31	3.29	61	47	32	3.50
58	41	27	2.78	59	43	28	2.97	60	44	29	3.17
57	38	24	2.47	58	40	25	2.65	59	42	26	2.85
56	35	21	2.16	57	37	22	2.33	58	39	23	2.52
55	31	18	1.85	56	34	19	2.01	57	36	20	2.19
54	28	16	1.65	55	30	17	1.80	56	32	18	1.97
53	24	13	1.34	54	26	14	1.48	55	28	15	1.64
52	19	10	1.03	53	22	11	1.17	54	24	12	1.31
51	13	8	.82	52	16	9	.95	53	20	10	1.09
50	5	5	.51	51	10	6	.64	52	13	7	.77
Dry Bulb 81° (11.28)				**Dry Bulb 82° (11.63)**				**Dry Bulb 83° (11.99)**			
80	80	96	10.83	81	81	96	11.17	82	82	96	11.51
79	78	92	10.38	80	79	92	10.70	81	80	92	11.03
78	77	88	9.93	79	78	88	10.24	80	79	88	10.55
77	75	84	9.48	78	77	84	9.79	79	78	84	10.07
76	74	80	9.02	77	75	80	9.30	78	76	80	9.59
75	73	76	8.57	76	74	76	8.84	77	75	76	9.11
74	71	72	8.12	75	72	72	8.37	76	73	73	8.76
73	70	69	7.78	74	71	69	8.03	75	72	69	8.27
72	68	65	7.33	73	69	65	7.56	74	70	66	7.91
71	66	61	6.88	72	67	61	7.10	73	69	62	7.43
70	65	58	6.54	71	66	58	6.75	72	67	59	7.08
69	63	55	6.20	70	64	55	6.40	71	65	56	6.72
68	61	51	5.75	69	62	51	5.93	70	64	52	6.24
67	59	48	5.42	68	60	48	5.58	69	62	49	5.88
66	57	45	5.08	67	59	45	5.23	68	60	46	5.52
65	55	41	4.63	66	57	42	4.89	67	58	42	5.04
64	53	39	4.40	65	55	39	4.51	66	56	40	4.80
63	51	36	4.06	64	52	36	4.19	65	54	36	4.32
62	49	33	3.72	63	50	33	3.84	64	52	34	4.08
61	46	30	3.38	62	48	30	3.49	63	49	31	3.72
60	43	27	3.05	61	45	28	3.26	62	47	28	3.36
59	41	24	2.71	60	42	25	2.91	61	44	25	3.00
58	38	21	2.37	59	39	22	2.56	60	41	23	2.76
57	34	19	2.14	58	36	20	2.33	59	38	20	2.40
56	31	16	1.81	57	33	17	1.98	58	35	18	2.16
55	27	13	1.47	56	29	14	1.63	57	31	15	1.80
54	22	11	1.24	55	25	12	1.40	56	27	13	1.56
53	17	9	1.02	54	20	10	1.16	55	23	11	1.32
52	10	6	.68	53	14	7	.82	54	18	8	.96

U. S. W. B. Psychrometric Tables, Continued.

Dry Bulb 84° (12.36)				Dry Bulb 85° (12.74)				Dry Bulb 86° (13.13)			
Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
°F	°F	%	Grs.	°F	°F	%	Grs.	°F	°F	%	Grs.
83	83	96	11.86	84	84	96	12.23	85	85	96	12.61
82	81	92	11.36	83	82	92	11.72	84	83	92	12.08
81	80	88	10.88	82	81	88	11.21	83	82	88	11.56
80	79	84	10.38	81	80	84	10.70	82	81	84	11.03
79	77	80	9.89	80	78	80	10.19	81	79	81	10.64
78	76	76	9.39	79	77	77	9.81	80	78	77	10.10
77	74	73	9.02	78	75	73	9.30	79	76	73	9.58
76	73	69	8.54	77	74	69	8.80	78	75	70	9.19
75	71	66	8.16	76	72	66	8.41	77	73	66	8.67
74	70	62	7.66	75	71	63	8.03	76	72	63	8.27
73	68	59	7.29	74	69	60	7.64	75	70	60	7.88
72	66	56	6.92	73	68	57	7.26	74	69	57	7.48
71	65	52	6.43	72	66	53	6.75	73	67	53	6.96
70	63	49	6.06	71	64	50	6.36	72	65	50	6.57
69	61	46	5.69	70	62	47	5.99	71	64	47	6.17
68	59	43	5.32	69	61	44	5.61	70	62	44	5.78
67	57	40	4.95	68	59	41	5.22	69	60	42	5.52
66	55	37	4.57	67	57	38	4.84	68	58	39	5.12
65	53	35	4.33	66	54	36	4.59	67	56	36	4.73
64	51	32	3.95	65	52	33	4.21	66	54	33	4.33
63	48	29	3.58	64	50	30	3.83	65	52	31	4.07
62	46	26	3.21	63	48	27	3.44	64	49	28	3.68
61	43	24	2.97	62	45	25	3.18	63	47	26	3.41
60	40	21	2.60	61	42	22	2.80	62	44	23	3.02
59	37	19	2.35	60	39	20	2.55	61	41	21	2.76
58	34	16	1.98	59	36	17	2.17	60	38	18	2.36
57	30	14	1.73	58	32	15	1.92	59	34	16	2.10
56	26	12	1.48	57	28	13	1.66	58	31	14	1.84

Dry Bulb 87° (13.53)				Dry Bulb 88° (13.94)				Dry Bulb 89° (14.36)			
86	86	96	12.99	87	87	96	13.38	88	88	96	13.79
85	84	92	12.45	86	85	92	12.83	87	86	92	13.21
84	83	88	11.90	85	84	88	12.27	86	85	88	12.64
83	82	85	11.50	84	83	85	11.85	85	84	85	12.21
82	80	81	10.96	83	81	81	11.29	84	82	81	11.63
81	79	77	10.42	82	80	77	10.73	83	81	77	11.06
80	78	74	10.00	81	79	74	10.32	82	80	74	10.63
79	76	70	9.47	80	77	70	9.76	81	78	70	10.05
78	75	67	9.06	79	76	67	9.34	80	77	67	9.62
77	73	64	8.66	78	74	64	8.92	79	75	64	9.19
76	72	61	8.25	77	73	61	8.50	78	74	61	8.76
75	70	57	7.71	76	71	57	7.95	77	72	57	8.18
74	68	54	7.31	75	69	54	7.53	76	71	54	7.75
73	67	51	6.90	74	68	51	7.11	75	69	51	7.32
72	65	48	6.50	73	66	48	6.69	74	67	48	6.89
71	63	45	6.09	72	64	46	6.41	73	66	46	6.61
70	61	43	5.82	71	62	43	6.00	72	64	43	6.17
69	59	40	5.41	70	61	40	5.58	71	62	40	5.74
68	57	37	5.01	69	59	37	5.16	70	60	37	5.31
67	55	34	4.60	68	57	35	4.88	69	58	35	5.03
66	53	32	4.33	67	55	32	4.46	68	56	33	4.74
65	51	29	3.92	66	52	30	4.18	67	54	30	4.31
64	48	27	3.65	65	50	27	3.76	66	51	28	4.03
63	46	24	3.25	64	47	25	3.49	65	49	25	3.59
62	43	22	2.98	63	45	22	3.07	64	46	23	3.30
61	40	19	2.57	62	42	20	2.79	63	44	21	3.02
60	36	17	2.30	61	38	18	2.51	62	41	18	2.59
59	33	15	2.03	60	35	15	2.09	61	37	16	2.30
58	29	12	1.62	59	31	13	1.81	60	34	14	2.01

U. S. W. B. Psychrometric Tables, Continued.

Dry Bulb 90° (14.79)				Dry Bulb 91° (15.23)				Dry Bulb 92° (15.69)			
Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
°F	°F	%	Grs.	°F	°F	%	Grs.	°F	°F	%	Grs.
89	89	96	14.20	90	90	96	14.62	91	91	96	15.06
88	87	92	13.60	89	88	92	14.01	90	89	92	14.44
87	86	89	13.16	88	87	89	13.55	89	88	89	13.98
86	85	85	12.57	87	86	85	12.95	88	87	85	13.33
85	83	81	11.98	86	85	82	12.49	87	86	82	12.87
84	82	78	11.53	85	83	78	11.88	86	84	79	12.39
83	81	74	10.94	84	82	75	11.42	85	83	75	11.78
82	79	71	10.50	83	80	72	10.97	84	81	72	11.30
81	78	68	10.06	82	79	68	10.36	83	80	68	10.68
80	76	65	9.61	81	78	65	9.90	82	79	65	10.20
79	75	61	9.02	80	76	62	9.44	81	77	62	9.73
78	73	58	8.58	79	75	59	8.99	80	76	59	9.26
77	72	55	8.14	78	73	56	8.53	79	74	56	8.79
76	70	52	7.69	77	71	53	8.07	78	73	53	8.32
75	69	49	7.25	76	70	50	7.62	77	71	50	7.85
74	67	47	6.95	75	68	48	7.31	76	69	48	7.53
73	65	44	6.51	74	66	45	6.85	75	68	45	7.07
72	63	41	6.07	73	65	42	6.40	74	66	42	6.59
71	61	39	5.77	72	63	40	6.10	73	64	40	6.28
70	59	36	5.32	71	61	37	5.64	72	62	37	5.81
69	57	34	5.03	70	59	35	5.33	71	60	35	5.49
68	55	31	4.59	69	57	32	4.87	70	58	32	5.02
67	53	29	4.29	68	55	30	4.57	69	56	30	4.71
66	51	26	3.85	67	52	27	4.11	68	54	28	4.39
65	48	24	3.55	66	50	25	3.81	67	51	25	3.92
64	45	22	3.26	65	47	23	3.51	66	49	23	3.61
63	43	19	2.81	64	44	20	3.05	65	46	21	3.30
62	39	17	2.52	63	41	18	2.74	64	43	19	2.98
61	36	15	2.22	62	38	16	2.44	63	40	17	2.67
60	32	13	1.93	61	35	14	2.13	62	37	15	2.36
59	28	11	1.63	60	31	12	1.83	61	33	13	2.04
58	24	9	1.33	59	27	10	1.52	60	29	11	1.73
57	19	7	1.04	58	22	8	1.22	59	25	9	1.41
56	11	5	.74	57	16	6	.92	58	20	7	1.10
55	1	3	.45	56	8	4	.61	57	13	5	.78
54	—17	1	.15	55	— 4	2	.30	56	4	3	.47
53	—	—	—	54	—40	1	.15	55	—13	1	.16

U. S. W. B. Psychrometric Tables, Continued.

Dry Bulb 93° (16.16)				Dry Bulb 94° (16.63)				Dry Bulb 95° (17.12)			
Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
°F	°F	%	Grs.	°F	°F	%	Grs.	°F	°F	%	Grs.
92	92	96	15.51	93	93	96	15.96	94	94	96	16.44
91	90	93	15.03	92	92	93	15.47	93	93	93	15.92
90	89	89	14.38	91	90	89	14.80	92	91	89	15.25
89	88	85	13.74	90	89	85	14.14	91	90	85	14.55
88	87	82	13.25	89	88	82	13.64	90	80	82	14.04
87	85	79	12.77	88	86	79	13.14	89	87	79	13.52
86	84	75	12.12	87	85	75	12.47	88	86	75	12.84
85	83	72	11.64	86	84	72	11.97	87	85	72	12.34
84	81	69	11.15	85	82	69	11.47	86	83	69	11.81
83	80	66	10.67	84	81	66	10.98	85	82	66	11.30
82	78	63	10.18	83	79	63	10.48	84	80	63	10.79
81	77	60	9.70	82	78	60	9.98	83	79	60	10.27
80	75	57	9.21	81	76	57	9.48	82	78	57	9.76
79	74	54	8.73	80	75	54	8.98	81	76	54	9.24
78	72	51	8.24	79	73	51	8.48	80	74	51	8.73
77	71	49	7.92	78	72	49	8.15	79	73	49	8.39
76	69	46	7.44	77	70	46	7.65	78	71	46	7.88
75	67	43	6.95	76	68	43	7.15	77	70	43	7.36
74	65	41	6.63	75	67	41	6.82	76	68	41	7.02
73	63	38	6.14	74	65	38	6.32	75	66	38	6.51
72	62	36	5.82	73	63	36	5.99	74	64	36	6.16
71	60	33	5.33	72	61	33	5.49	73	62	34	5.82
70	58	31	5.01	71	59	31	5.16	72	60	31	5.31
69	55	29	4.69	70	57	29	4.83	71	58	29	4.96
68	53	26	4.20	69	55	27	4.49	70	56	27	4.62
67	51	24	3.88	68	52	24	3.99	69	54	25	4.28
66	48	22	3.56	67	50	22	3.66	68	52	23	3.94
65	45	20	3.23	66	47	20	3.33	67	49	21	3.60
64	42	18	2.91	65	44	18	2.99	66	46	19	3.25
63	39	16	2.59	64	41	16	2.66	65	43	17	2.91
62	36	14	2.26	63	38	14	2.33	64	40	15	2.57
61	32	12	1.94	62	34	12	2.00	63	37	13	2.23
60	28	10	1.62	61	30	10	1.66	62	33	11	1.88
59	23	8	1.29	60	26	9	1.50	61	29	9	1.54
58	17	6	.97	59	21	7	1.16	60	24	7	1.20
57	10	4	.65	58	14	5	.83	59	19	6	1.03
56	— 2	2	.32	57	6	3	.50	58	11	4	.69
55	—28	1	.16	56	— 9	1	.17	57	1	2	.34

U. S. W. B. Psychrometric Tables, Continued.

Dry Bulb 96° (17.63)				Dry Bulb 97° (18.14)				Dry Bulb 98° (18.67)			
Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
°F	°F	%	Grs.	°F	°F	%	Grs.	°F	°F	%	Grs.
95	95	96	16.93	96	96	96	17.41	97	97	96	17.92
94	94	93	16.40	95	95	93	16.87	96	96	93	17.36
93	92	89	15.69	94	93	89	16.60	95	94	89	16.62
92	91	86	15.16	93	92	86	15.16	94	93	86	16.06
91	90	82	14.46	92	91	82	14.88	93	92	83	15.50
90	88	79	13.93	91	89	79	14.33	92	90	79	14.75
89	87	76	13.40	90	88	76	13.79	91	89	76	14.19
88	86	73	12.87	89	87	73	13.24	90	88	73	13.63
87	84	69	12.17	88	85	69	12.52	89	87	70	13.07
86	83	66	11.64	87	84	66	11.97	88	85	67	12.51
85	82	63	11.11	86	83	63	11.43	87	84	64	11.95
84	80	61	10.75	85	81	61	11.07	86	82	61	11.39
83	79	58	10.23	84	80	58	10.52	85	81	58	10.83
82	77	55	9.70	83	78	55	9.98	84	79	56	10.45
81	76	52	9.17	82	77	52	9.43	83	78	53	9.90
80	74	50	8.82	81	75	50	9.07	82	76	50	9.34
79	72	47	8.29	80	74	47	8.53	81	75	48	8.96
78	71	44	7.76	79	72	44	7.98	80	73	45	8.40
77	69	42	7.40	78	70	42	7.62	79	72	43	8.03
76	67	39	6.88	77	69	39	7.07	78	70	40	7.47
75	66	37	6.52	76	67	37	6.71	77	68	38	7.10
74	64	35	6.17	75	65	35	6.35	76	66	36	6.73
73	62	32	5.64	74	63	33	5.99	75	64	34	6.35
72	60	30	5.29	73	61	31	5.62	74	63	32	5.97
71	58	28	4.93	72	59	28	5.08	73	61	29	5.42
70	55	26	4.58	71	57	26	4.72	72	58	27	5.04
69	53	24	4.23	70	55	24	4.36	71	56	25	4.67
68	51	22	3.88	69	52	22	3.99	70	54	23	4.29
67	48	20	3.53	68	50	20	3.63	69	52	21	3.92
66	45	18	3.17	67	47	18	3.27	68	49	19	3.55
65	42	16	2.82	66	44	16	2.91	67	46	17	3.17
64	39	14	2.47	65	41	14	2.54	66	43	15	2.80
63	35	12	2.12	64	38	13	2.36	65	40	14	2.62
62	31	10	1.76	63	34	11	2.00	64	36	12	2.24
61	27	8	1.41	62	30	9	1.63	63	32	10	1.90
60	22	7	1.23	61	25	7	1.27	62	28	8	1.49
59	16	5	.88	60	20	6	1.09	61	23	7	1.31
58	8	3	.53	59	13	4	.73	60	17	5	.93
57	−5	2	.35	58	3	2	.36	59	10	3	.56
56	—	—	—	57	−15	1	.18	58	−2	2	.37

U. S. W. B. Psychrometric Tables, Concluded.

Dry Bulb 99° (19.21)				Dry Bulb 100° (19.77)				Dry Bulb 101° (20.34)			
Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.	Wet Bulb	Dew Point	Rel. Hum.	Act. Hum.
°F	°F	%	Grs.	°F	°F	%	Grs.	°F	°F	%	Grs.
98	98	96	18.44	99	99	96	18.98	100	100	96	19.53
97	97	93	17.87	98	98	93	18.39	99	99	93	18.92
96	95	89	17.10	97	96	89	17.60	98	97	89	18.10
95	94	86	16.52	96	95	86	17.00	97	96	86	17.49
94	93	83	15.94	95	94	83	16.41	96	95	83	16.88
93	92	80	15.37	94	93	80	15.82	95	94	80	16.27
92	90	77	14.79	93	91	77	15.22	94	92	77	15.66
91	89	73	14.02	92	90	73	14.43	93	91	73	14.85
90	88	70	13.45	91	89	70	13.84	92	90	70	14.24
89	86	68	13.07	90	87	68	13.44	91	88	68	13.83
88	85	65	12.49	89	86	65	12.85	90	87	65	13.22
87	83	62	11.91	88	85	62	12.26	89	86	62	12.61
86	82	59	11.33	87	83	59	11.67	88	84	59	12.00
85	81	56	10.76	86	82	56	11.08	87	83	56	11.39
84	79	54	10.38	85	80	54	10.68	86	81	54	10.98
83	78	51	9.80	84	79	51	10.08	85	80	51	10.37
82	76	49	9.41	83	77	49	9.69	84	78	49	9.96
81	74	46	8.84	82	76	46	9.10	83	77	46	9.35
80	73	44	8.45	81	74	44	8.70	82	75	44	8.95
79	71	41	7.88	80	72	41	8.11	81	74	41	8.34
78	69	39	7.49	79	71	39	7.71	80	72	39	7.93
77	68	37	7.11	78	69	37	7.32	79	70	37	7.54
76	66	35	6.72	77	67	35	6.92	78	69	35	7.12
75	64	33	6.34	76	65	33	6.52	77	67	33	6.71
74	62	30	5.76	75	63	30	5.93	76	65	31	6.31
73	60	28	5.38	74	61	28	5.54	75	63	29	5.90
72	58	26	5.00	73	59	26	5.14	74	61	27	5.49
71	56	24	4.61	72	57	24	4.74	73	59	25	5.09
70	53	22	4.23	71	55	22	4.35	72	56	23	4.68
69	51	20	3.84	70	52	21	4.15	71	54	21	4.27
68	48	18	3.46	69	50	19	3.76	70	52	19	3.86
67	45	16	3.08	68	47	17	3.36	69	49	17	3.46
66	42	15	2.88	67	44	15	2.97	68	46	15	3.05
65	39	13	2.50	66	41	13	2.57	67	43	14	2.85
64	35	11	2.11	65	37	12	2.37	66	40	12	2.44
63	31	9	1.73	64	33	10	1.98	65	36	10	2.04
62	26	8	1.54	63	29	8	1.58	64	32	9	1.83
61	21	6	1.15	62	25	7	1.38	63	28	7	1.43
60	15	4	.77	61	19	5	.99	62	23	6	1.22
59	6	3	.58	60	12	4	.79	61	17	4	.81
58	—10	1	.19	59	1	2	.40	60	8	3	.61
57	——	——	——	58	—22	1	.20	59	—5	1	.20

Note.—In hygrometrical and psychrometrical readings, the dry bulb temperatures are the same, viz., the temperature of the air.

The wet bulb temperatures, however, are different, although the wet bulb temperatures indicated by both instruments are temperatures of evaporation; in the case of the hygrometer, the temperature of evaporation is that of undisturbed or stagnant air, whereas, in the case of the psychrometer, the temperature of evaporation is lower because the evaporation takes place more rapidly and with correspondingly increased cooling effect, because the wet bulb is exposed to a draft of air of approximately fifteen feet per second velocity.

And so, it will be seen that wet bulb temperatures vary all the way from hygrometric to psychrometric, depending entirely upon the velocity of the draft of air to which the wet bulb is exposed. Hence, the importance of keeping hygrometers out of air currents, and of slinging psychromoters fast enough to expose the wet bulb at the requisite velocity.

II.

ATMOSPHERIC CONDITIONS AFFECTING HEALTH

Impurities in Air.

As before stated, "Pure Air" is composed of Oxygen and Nitrogen in the proportion of approximately 21 and 79% respectively, with traces of carbon dioxide (CO), aqueous vapor, ammonia and some rare gases such as argon, krypton, etc. Air is termed "Foul" when the proportion of carbon dioxide becomes excessive, when it is impregnated with offensive matter, or when it carries in suspension dust and "fly" of any sort deleterious to health.

Requirements for Life.

The element necessary for life, as is well known, is Oxygen; lessening the supply of Oxygen causes great physical distress; increasing the percentage of Oxygen gives a feeling of exhiliration.

Requirements for Health.

In nature the balance is maintained by the operation of well known agencies, the proportion of CO_2 being as low as 3 to 4 parts in 10,000 in the country. In cities and particularly in the vicinity of certain industrial plants the percentage is greatly increased, which accounts for the greater "freshness" of air in the country districts. The menace to health, as shown elsewhere, is not so much the character and kind of air but that it is a carrier of microbes which breed disease.

While extreme dryness may help some acute cases of lung trouble, to a normal person extremes in humidity in either direction are hurtful, as will be pointed out in a succeeding paragraph.

The effects of what may be termed "poisonous gases and vapors" occasionally met with in mining, metallurgical and chemical works are not pertinent to this discussion and so will not be considered.

Carbon Dioxide.

Carbon dioxide (carbonic acid gas) is a chemical compound consisting of one part carbon and two parts oxygen. It is a gas and is best known as the product of respiration; a part of the oxygen in the fresh air taken into the lungs unites with the carbon in the blood resulting from the broken down tissues of the body, forming carbon dioxide, which is exhaled with the remaining constituents of the air unchanged. CO_2 is also formed by combustion of coal and the oxidation of decaying organic matter. The present annual combustion

of coal, about 900 million tons, adds about 1-700 part to the entire carbon dioxide existing in the atmosphere; volcanism is also always pouring immense quantities of carbon dioxide into the atmosphere. The balance in proportion of carbon dioxide in the atmosphere is maintained by various agencies: the ocean, for instance, absorbing it acts as a regulator of huge capacity which takes up about 5-6 of the entire excess; the weathering of minerals decomposed by the CO_2 in air and water, also takes care of a large proportion of it; and plant life, absorbing carbon dioxide, secreting the carbon and exhaling the oxygen, takes care of the balance of it. A consideration of these conditions makes pertinent the observation that so far as carbon dioxide is concerned, air exists at its greatest purity along the wooded shores of seacoasts far away from volcanic activity; any location along a seacoast is probably next in order; wooded country districts are probably next; cities or centers where a great deal of fuel is burned are naturally considerably lower in the scale, seacoast cities being least so, and interior cities being the lowest.

Standards of Purity.

"Fresh Air" is not supposed to contain over 7 parts of CO_2, and in many countries an excess of 9 parts is prohibited by legal enactment in all factories and work places.

Amount of Air Required for Ventilation.

The average person breathes 18 times per minute and takes in 25 cubic inches at each inspiration, thereby consuming 15.6 cubic feet of air per hour. The air breathed out, or exhaled, contains 500 parts of CO_2: to reduce this to 9 parts therefore requires approximately 1200 to 1500 cubic feet of fresh air per hour per operative.

Solubility of CO_2 in Water.

But, CO_2 is quite soluble in water, and so this amount of air for ventilation can be greatly reduced, even cut in half, by an efficient system of humidifiers, in which the air is washed by a spray, the surplus waste water carrying off a large part of the CO_2 and liberating it again by the process of aeration that takes place as the waste water falls splashing into the tank from the return pipes.

Dust and "Fly" in the Atmosphere a Menace to Health.

Every thinking person admits that the presence of "fly" in the air is detrimental to health. While the hairs in the nostrils and the warm sticky mucous membranes catch a great deal of it before it gets far, no one doubts that a great deal of it finds its way into the lungs. Owing to its fibrous and relatively insoluble character and to the very appreciable size of the constituent particles, when once lodged it is extremely difficult of dislodgement or absorption. But, owing to the fineness of its particles, dust does not get credit for it, although it is the worse offender of the two. Relatively few

people have ever seen dust collected in quantity; it is worth while for any one interested in the subject to examine some of the dust collected by a Vacuum Cleaning Process, and the dust from places that it would naturally seem should be the cleanest appears to be the least so. Note the greasy, dark brown impalpable powder collected from some hotel or fine residence which is most immaculately kept. When it is realized that bacteria do not float around by themselves, but collect and propagate most freely on dust, each particle being the habitat for many thousands of them, a fair conception can be obtained of the myriads not only collected in corners and out of the way places, but also floating about in the air of every place where human beings are congregated in numbers and where no systematic effort is made to get them out. Look also at a beam of sunlight through a mill window in even the cleanest room, the amount of dust seen floating is surprising. Now if there is systematic air washing going on whereby the dust when first liberated from the raw material in process of manufacture is largely removed, it is clear that not only will the bulk of the bacteria be caught and removed also, but that which remains can be breathed with impunity because the few remaining are not sufficient to overthrow the defensive powers of the systems of the operatives who breathe it. What may be termed stale dust is the dangerous dust, that which even though not very great in quantity yet where each particle has time under favorable conditions of humidity and temperature to act as a hot bed for the propagation of microbes; what may be termed fresh dust is relatively free from them.

Extremes in Humidity Injurious to Healt h.

Sanitarians are agreed that whichever conditions prevail, whether excessive moisture or excessive dryness, the effect upon the lungs is pretty much the same; the lining membrane of the air passages is irritated to such an extent that transpiration is impeded, and the tendency to disease developed. Excessive dryness is highly injurious, furthermore, because, as mentioned elsewhere, it is conducive to dust and fly in the atmosphere of rooms where manufacturing is carried on, a condition that causes many bronchial and pulmonary diseases. Extreme humidity is noticeably oppressive and debilitating especially in warm days because the low evaporative power of the very moist atmosphere does not rapidly enough dry up the perspiration thrown off by the body through the skin in the effort to reduce its own excessive heat. In weave sheds in particular working with high percentages of size in the warps, such extreme humidities have been resorted to in many cases that the English Government, after a careful investigation, enacted a law establishing maximum limits of humidity at different temperatures to protect the work people; these requirements are given in the accompanying table and, as would be in-

ferred, the range of humidities in that Act is based entirely upon considerations of the personal comfort of the operatives and has absolutely no relation to conditions favorable to manufacture.

Cotton Cloth Factories Act, 1889.

Maximum limits of humidity of the atmosphere at different temperatures.

(The figures for regain I have inserted myself, and will discuss in Chapter VII.)

Dry Bulb Tempera-tures.	Wet Bulb Temperatures		Dew Point Tempera-tures.	Humidities.		Regain.	
	Hygro-metric.	Psycho-metric.		Act. Hum. Grs.	Rel. Hum. %	Cotton %	Wor-sted %
100	91.00	88.70	86	12.70	64.00	7.3	14.4
99	90.00	87.80	85	12.30	64.00	7.3	14.4
98	89.00	87.00	84	12.00	64.00	7.3	14.4
97	88.50	86.60	84	11.90	65.50	7.5	15.0
96	88.00	86.00	83	11.80	66.00	7.7	15.1
95	87.00	85.00	82	11.50	66.00	7.7	15.2
94	86.00	84.00	81	11.10	66.00	7.7	15.3
93	85.50	83.80	81	11.00	68.00	8.0	15.7
92	84.50	83.00	80	10.70	68.00	8.0	15.8
91	83.50	82.00	79	10.35	68.00	8.0	15.8
90	83.00	81.50	79	10.30	69.00	8.2	16.1
89	82.50	81.00	78	10.25	71.00	8.5	16.3
88	81.50	80.25	77	9.90	71.00	8.5	16.3
87	80.50	79.25	76	9.55	71.00	8.5	16.3
86	80.00	78.70	76	9.50	72.00	8.6	16.9
85	79.00	77.75	75	9.20	72.00	8.7	16.9
84	78.00	76.80	74	8.90	72.00	8.7	16.9
83	77.50	76.30	73	8.85	74.00	9.1	17.4
82	76.50	75.50	73	8.65	74.00	9.1	17.5
81	76.00	75.10	73	8.60	76.00	9.3	17.8
80	75.50	74.60	73	8.55	77.50	9.6	18.2
79	74.50	73.60	71	8.25	77.50	9.6	18.3
78	73.50	72.50	70	8.00	77.00	9.6	18.3
77	73.00	72.00	70	8.00	79.00	9.9	18.7
76	72.00	71.25	69	7.70	79.00	9.9	18.8
75	71.50	70.75	69	7.65	81.50	10.3	19.4
74	70.50	69.90	68	7.40	81.50	10.3	19.5
73	70.00	69.50	68	7.40	84.00	10.8	20.0
72	69.00	68.50	67	7.10	84.00	10.8	20.1
71	68.50	67.90	67	7.10	85.50	11.1	20.4
70	68.00	67.50	66	7.10	88.00	11.5	21.4
69	67.00	66.50	65	6.90	88.00	11.5	21.4
68	66.00	65.50	64	6.60	88.00	11.6	21.5
67	65.00	64.50	63	6.40	88.00	11.6	21.5
66	64.00	63.75	63	6.20	88.00	11.6	21.6
65	63.00	62.75	62	6.00	88.00	11.7	21.7
64	62.00	61.75	61	5.80	88.00	11.7	21.8
63	61.00	60.75	60	5.60	88.00	11.7	21.9
62	60.00	59.80	59	5.40	88.00	11.7	21.9
61	59.00	58.80	58	5.20	88.00	11.7	22.0
60	58.00	57.80	57	5.10	88.00	11.8	22.1

Note.—It is not out of place to remark just here that the Act also prescribed the standard of purity for the atmosphere, limiting the CO_2 to less than 9 parts in 10,000, which condition was to be maintained by suitable ventilation, the minimum amount of which shall not be less than 600 cubic feet per operative per hour.

A Few Academic Observations upon Respiration.

The average mill man is not particularly concerned with the physiology of respiration, nor in the chemical and physical changes in air and blood that take place during respiration. There are always those, however, who want to go more or less into details, and to whom the follow-lowing observations are briefly directed:

As already stated, the inspired air, that is the atmospheric air, is a mixture of gases in the following proportions, by volume: nitrogen approximately 79%, oxygen 20.96% and carbon dioxide or carbonic acid gas 0.04%. Argon, krypton and other rare gasses have not been shown to have any physiological significance in respiration, and are, therefore, included with nitrogen, the inert proportion of the mixture.

The expired air varies, of course, with the composition of the air inspired, and with the depth of the expiration; under normal conditions it contains nitrogen and other rare gases 79%, oxygen 16.02%, and carbon dioxide 4.38%.

The only change that has taken place, therefore, is in the relative proportion of oxygen and carbon dioxide; the former having been reduced by 4.94% and the latter having been increased by 4.34%. In short, the respired air has lost oxygen and has gained carbon dioxide, and consequently the blood has absorbed oxygen for the elimination of carbon. The fact that the volume of oxygen absorbed is greater than the volume of carbon dioxide given off is explained by the oxygen not only having been consumed to oxidize the carbon, but also because it oxidizes the small percentage of free hydrogen in the blood, which is either exhaled as watery vapor or is excreted as water, or both.

The temperature of the air we breathe is of considerable consequence, and likewise the percentage of moisture it contains. As expired air is warmed to approximately the temperature of the body and nearly saturated, it is evident that under normal conditions the act of respiration entails upon the body a loss of heat and water, for the inspired air is generally much cooler than the body and of comparatively low relative humidity. Breathing, in fact, is a subsidiary means of regulating the temperature of the body. Apart from the injurious effect, therefore, upon the lining membranes of the air passages in the lungs as already noted, extremes of humidity and temperature on either side interfere with the customary functioning of the body, throwing additional work elsewhere to overcome that irregularity.

As immediately bearing upon the subject of ventilation, and concerning the question of sufficiency of ventilation, it is interesting to know that best authority inclines to the following opinion:

(1) Variations in the amount of nitrogen in the inspired air have no distinct physiological effect.

(2) A slight increase in the proportion of oxygen produces exhilaration; a very material increase in the amount of oxygen and long continued causes death with convulsions.

(3) Contrary to the generally accepted theory of ventilation, whereby the proportion of carbon dioxide shall not exceed .07 of 1%, the actual presence of an excess in small amount of carbon dioxide in the air over and above that amount produces no marked effect: it is not until two or three per cent. is reached that noticeable discomfort occurs; increasing the amount further, death ensues, but without convulsions as in the case of death through increasing the amount of oxygen.

There is by no means sufficient proof to show that breathing expired air within reasonable limits produces the feeling of discomfort such as headaches and depression, commonly noticed in a badly or illy ventilated room. It has sometimes been assumed that these effects are due to the vitiated air direct, in the nature of a toxic or poison; this view is now also discredited. The perceptibly disagreeable odor noticed immediately upon entering a crowded and illy ventilated room is more likely due to foul smelling breath, to disagreeable bodily exhalation, to sweat, and like noxious causes. The deficiency in oxygen undoubtedly causes more of the feeling of depression and headache than the increase of carbon dioxide. Some of the best physiologists, however, attribute the definitely known evil results of breathing air in illy ventilated rooms to increased temperature and moisture.

The removal of these noxious odors, dust and lint, and a considerable proportion of carbon dioxide, thereby relatively increasing the proportion of oxygen at the same time—all of these desiderata can be largely accomplished by the simple expedient of air washing.

From all of which it is quite certain that ventilation is by no means more important than air cleansing; that supplying additional fresh air to keep the percentage of carbon dioxide down within the usually accepted limit is by no means adequate and should be supplemented by thorough air cleansing, which air cleansing should furthermore be accomplished by positive air washing. And finally that the automatic regulation of humidity and temperature is probably more necessary than any other consideration.

The effect of Temperature and Humidity upon the Heat Regulation of the Body.

Considering that two to three quarts of sweat is the average quantity thrown off by an average person clothed, the evaporation of which is one of the principal agents for cooling the body, it becomes quite a matter of concern that the air is not too dry so that the temperature of evaporation (which is the wet bulb temperature) is not too low, thereby exerting too much cooling effect; and on the other hand, that the air is not

so moist that the process of evaporation is interfered with and goes on too slowly and the temperature of evaporation not low enough to produce the desired cooling effect. The amount of heat lost from the body by relatively thick or thin clothing is not pertinent to this subject, even though it be the means of disposing of the major part of all the surplus heat of the body; that can easily be taken care of by suitable clothing. The question of evaporation of sweat from the body, however, is a different matter, and an important one, too, for over 15% of the body heat is dissipated that way.

Humidity in Textile Mills.

(Reprinted from Textile World Record, February, 1908.)

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"Air is also moistened by blowing steam into the work rooms, this being popularly known as "steaming," and for the abolition of which there is a movement now under way in England.

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"The overwhelming majority against steam is based on the conviction that the practice is injurious to the health of the operatives.

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"The question as to the effect of degging, steaming and other methods of air moistening on the health of the operatives is one that will not down. It will never be settled until it is settled right. What are the facts? A commendable attempt to answer that question has been made by Mr. Scarisbrick, who secured the following statement from Dr. F. G. Haworth, health officer at Darwen, England:

Health Department, Municipal Offices,
Darwen, March, 1907.

Dear Sir: Before I touch the question of your letter as to the introduction of steam into weaving sheds being injurious or not, let me make perfectly clear the position which carbonic acid gas plays in the economy of Nature.

In the purest mountain air the average amount of this gas is three parts in 10,000. The amount present in ordinary atmospheric air is four parts in 10,000; in overcrowded rooms it often reaches as high as 30 parts per 10,000. Sanitarians have established a basis whereon any amount over 6 parts in 10,000 parts is regarded as indicating concomitant and injurious organic impurities of which carbonic acid gas is the necessary yet harmless index. This gas per se, does not begin to be injurious until a proportion of about 150 parts in 10,000 is reached.

The carbonic acid gas in the atmosphere is contributed to by respiration—this accounts for its presence in crowded assemblies—combustion, and putrefaction, and is diminished by vegetation, and dispersed by rain and high winds. So that when I

speak of carbonic acid gas and its deleterious effects, I really have in mind not a gas, but organic impurities from various sources which are decidedly harmful, and which increase pro rata with the gas.

We have, therefore, in rooms in which large numbers of people are at work an atmosphere impregnated with impurities from imperfect combustion of gas, from the lungs, and from the skins of the persons themselves; but more vital in consequence are the germs of micro-organisms which are found in large numbers in the vicinity of the people. Some micro-organisms play a useful part in nature's work; others are injurious. Such are the bacilli of consumption and diphtheria and the coccus of pneumonia, which from recent investigation have been found in the saliva, the mouth, and the throat of even healthy individuals.

The following table shows the results of the analysis of airs by Drs. Carnelly, Haldane, and Anderson, and confirm this point I am making:

Cubic Feet Per Head.	Temperature.	CO_2 per 1,000 vols.	Organic Matter.	Microbes Per Cubic Foot.
100-180	55° F.	1.15	15.1	2267
180-260	55° F.	1.07	15.1	1398
260-340	53° F.	1.03	11.8	906
340-500	57° F.	0.93	8.4	1190
500-1000	54° F.	0.86	5.6	170
1000-2500	53° F.	0.67	3.9	255
2500-4000	57° F.	0.79	5.0	368

* * * * * * * * *

It may be looked upon as an axiom that "the sputum of a consumptive is always a source of danger as long as it is dry, to be wafted about by every current of air, but is perfectly safe when wet or weighed down with moisture, artificial or otherwise."

* * * * * * * * *

To sum up, in my opinion the introduction of moisture into the air of weaving sheds by artificial means is calculated to benefit the workers providing the relative humidity is kept within reasonable limits of the outside air; that its action on suspended particles, whether dust or microbes, is beneficial; that the workers therein are not more susceptible to such diseases as pneumonia, bronchitis, consumption and rheumatism than other people, in which opinion statistics bear me out; and that the agitation against its use has its foundation in a misconception of the whole matter.

I am, yours sincerely,

F. G. HAWORTH.

(Dr. Haworth, it will be noticed, qualifies his approval of air moistening by the clause, *"providing the relative humidity is kept within reasonable limits of the outside air."*)

* * * * * * * * * *

"On one point there can be little chance for dispute, namely, the need for regulating the moisture in mills. Such regulation is of importance not only for the protection of the operatives, but as affecting the efficiency of the mill as regards both the quality of the work and the amount of production.

* * * * * * * * * *

"It is difficult to lay too much emphasis on the importance of careful scientific methods in this process of air moistening.

The health of the operatives and the efficiency of the mill are involved to a very considerable extent. In spite of these facts the subject is but imperfectly understood by manufacturers; in many mills no attempt is made to study and regulate the moistening of the air in order to protect the operative and obtain the best results; no general rule or standard is accepted by the mills; and the mill manager who realizes the importance of the process and seeks intelligently to determine the facts is the exception to the rule.

* * * * * * * * * *

"During the past two years the Massachusetts Board of Health has investigated this question in the course of a general inquiry ordered by the legislature, and from the report recently submitted we make the following extract:

> Having considered some of the larger work-rooms with especial reference to insufficient light and to the presence of dust together with other unsanitary influences, attention should be called to the facts concerning the introduction of artificial moisture.
>
> A special study of 80 weave rooms was made. In 57 of these rooms the so-called steam vapor pot system was found. *In 18 rooms there was excessive moisture; in 4 of these excessive heat.* In 20 rooms the drosophore or some other modern system (with or without the vapor steam) was found, showing that the modern systems are fast gaining ground. *In 9 there was excessive heat, and in no one of these 9 rooms was there any attempt to regulate the temperature; in 7 rooms there were no thermometers.*
>
> The investigation showed conclusively that scarcely any effort is made on the part of most manufacturers to ascertain the definite conditions with respect to heat and moisture favorable to weaving by the use of acurate thermometers and hygrometers. The raising of humidity is done in a very unworkmanlike manner. In 23 of the 80 rooms there were no hygrometers; in 2 rooms where hygrometers were present, they were broken, and in a large number of rooms, 1 or more hygrometers were found to be unserviceable. *In the great majority of instances where hygrometers were used the instruments were untrustworthy.*
>
> Agents or superintendents of a few corporations, on the other hand, have made careful and extensive inquiries in order to determine "what constitutes the best working conditions and what degree of atmospheric humidity for a given temperature will give the best results," on the ground that the information obtained may be, from a commercial point of view, of great importance.

"How far other states are behind even Massachusetts in this matter may be judged from the following extract from the recent report of the New York commissioner of labor, who frankly confesses to the general ignorance of the subject, and bases his plea for regulation on the ground that it is recognized as important abroad:

> The laws (of New York) do not regulate "humidity." This is one of the most important subjects of regulation abroad. As it is an unknown subject to our inspectors it cannot be affirmed that it needs regulating here, but there is a fair presumption that it does.

"An agitation of the subject cannot fail to be of great benefit. It will direct the attention of manufacturers to the importance of a process now sadly neglected. It will lead to

protection of the health of the operatives. It will result in more perfect goods and in greater efficiency of both operatives and machinery. A better understanding of the question and a more scientific regulation of the process will enable manufacturers to effect large savings in the selection of raw material. Under present haphazard methods there is no question but that for many grades of goods more expensive material is required than would be needed if the atmospheric humidity of the work-rooms were kept more uniform and more in conformity with the technical requirements."

Extract from *New York Herald,* January 17, 1900, dated at Albany, New York.—The annual report of John Williams, Commissioner of Labor for the State of New York, has just been submitted to the Legislature, and contains the statement that the ventilation in factories throughout the State is a menace to the health of employes, this being the declaration of the State Medical Inspector of Factories:

> "In all 430 tests of air in different work-rooms were made," the report reads. "Twelve parts of carbonic acid gas are regarded as the maximum if air is to be wholesome for breathing. A tabulation of the inspector's tests shows proportions frequently two or three times greater than this and in some instances five and six times greater. The rather startling conditions revealed by these tests fully justify the provision made for a medical inspector, whose work gives the department a truly scientific basis on which to proceed in the matter of requiring sufficient ventilation in factories."

As I have referred to the English Cotton Cloth Factories Act, it is not out of place to quote a well known English authority, Sir Benjamin Dobson; the following extract from his "Humidity in Cotton Spinning" will no doubt prove both pertinent and interesting:

> "The question of humidity is intimately allied with that of temperature, and in manufactories it is first necessary to fix the temperature at which the work-room shall be kept, and then to make such arrangements that this air may be supplied with the amount of moisture sufficient to make the air soft enough for the comfort of the work-people and the conditioning of the fibre and to render the atmosphere a sufficiently good conductor to subtract the extraneous and superfluous electricity."

III.

ATMOSPHERIC CONDITIONS AFFECTING MANUFACTURING.

Textile Fibres affected by Atmospheric Conditions.

Although there are many fibres upon which atmospheric conditions have a greater or lesser effect, especially in the processes of manufacture, yet it is only a matter of degree; a consideration of any one of them will, therefore, be quite sufficient in this chapter, and the cotton fibre may be chosen as a representative one.

The Cotton Fibre, and its Working as affected by Atmospheric Conditions.

The structure of the cotton fibre, its hollow spiral or collapsed tubular form, with its delicate waxy walls, and its wonderful adaptitude for draughting and twisting and manipulating under proper atmospheric conditions, are well known, as well as its refractory nature under adverse conditions of humidity and temperature, and its fretful disposition in the presence of static electricity. The direct result of changes in humidity and temperature of the atmosphere is a corresponding change in the amount of moisture hygroscopically contained in fibres exposed to it, which in turn effects a consequent and relative change in their physical condition; these physical changes are mainly in the nature and amount of the twist in individual fibres, and in the extent of their brittleness or pliability as the case may be.

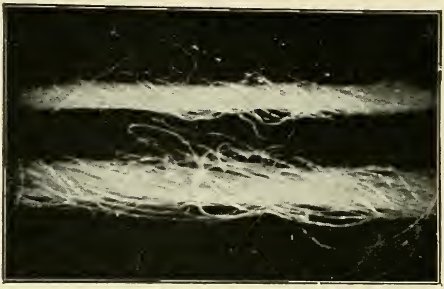
Normal Amount of Moisture in Cotton.

The normal amount of moisture in cotton is variously estimated from 7½ to 8½%, all of which estimates are doubtless equally correct as the amount of moisture varies with the locality in which the cotton grew and upon climatic variations from year to year. There is a very marked difference in the physical properties of one crop as compared to another, and any attempt to work one year's product with hard and fast rules deduced from the previous one will be disappointing; the behavior of one crop when worked at a certain standard of moisture in the different departments is a guide for the next one, but not an infallible rule. Again, the problem is complicated by the variable amount of oil in the fibre,—many planters now realizing the advantage of leaving the seed in the cotton as long as possible before ginning, so that the fibre may absorb as much oil as possible.

Effect of the Presence of Moisture on the Appearance of Yarn.

As to the effect of humidity on the appearance of yarn, the following cut shows a micrograph illustrating it.*

The yarn above was spun with relative humidity at 80% and the yarn below at 45%, both being the same counts, at the same temperatures, and all other conditions the same. The yarn spun at low humidity appears to be twice as large as the other, and is not so close, compact and smooth; furthermore, the drier the atmosphere in which it is spun the more "oozy" the yarn. It is interesting to note, however, that after 65% humidity was passed, it was impossible to distinguish any difference in the appearance of the yarn. From all of which it appears that yarns spun in an atmosphere of 65% relative humidity and above, appear to the best advantage,—although an increase of the humidity beyond 65% adds nothing further to its appearance.



(Beaty)

The Effect of Drying and Dampening Cloth.

It appears that the alternate moistening, drying and moistening of woven cotton fabrics do not materially effect their strength, as is shown by the following tests made by the Industrial Society at Mulhousen.

Normal Strength of Cloth	100
Saturated with Moisture	104
Dried on Hot Cylinders	86
Again Dampened	103

*Note.—The percentages of relative humidity were taken with a hygrometer and their accuracy is therefore open to question; still, they answer well enough for purposes of comparison.

Effect of Moisture on the Breaking Strength of Yarn.

Mr. J. H. M. Beaty, while head of the Textile Department, and Mr. B. M. Barker, Instructor of Carding and Spinning, Clemson College, S. C., conducted a series of tests along this line; and, as was to be expected, the results agree very closely with those of other reliable observers who have taken records both in an experimental way and from actual experience in mills. These Clemson tests were made with the temperature of the room varying from 65 to 85 degrees, no attempt being made to keep a record of the different temperatures. It is to be regretted that this record of temperatures was omitted, as it figures quite prominently in other data collected. In connection with the Clemson tests, however, it is stated that so far as could be seen, changes in temperature did not have any effect on the yarn, as two tests of yarn of the same size, run at the same humidity, but at temperatures of 68 and 83 degrees, gave a variation of only 1½ pounds in the average breaking strength and no difference in the appearance or running. The Clemson tests may be summarized as follows:

(20s Yarns)

Lowest Humidity, 40% Breaking Strength, 82.4 pounds.
Highest Humidity, 81% Breaking Strength, 101.5 pounds.
Difference in Humidity, 41%
Difference in Breaking Strength of Yarn, 19.1 pounds.

(25s Yarns)

Difference in Humidity, 44% (84-40.)
Difference in Breaking Strength of Yarns, 11.4 pounds.

(30s Yarns)

Difference in Humidity, 49% (95-46.)
Difference in Breaking Strength of Yarns, 19.2 pounds.

(35s Yarns)

Difference in Humidity, 47% (86-39.)
Difference in Breaking Strength of Yarns, 14.9 pounds.

From all of which the following conclusions were drawn:

"First.—As a rule, the higher the humidity, the higher the breaking strength of the yarn.

"Second.—That the percentage of broken ends was less with the humidity at from 65 to 75.

"Third.—The fibres in the yarns lay closer together as the humidity was increased, producing a more compact and less fuzzy yarn, also a yarn that looked smaller. After the humidity was raised to about 70 there was scarcely any difference in the appearance of the yarns.

"Fourth.—The higher the humidity the less "fly" collected on the frames.

"From these four conclusions it would appear that, all things being taken into consideration, a humidity between 65 and 75 would give the best results in the spinning room. Above this a little stronger yarn might be obtained, but its appearance would not be any better and the chances are that broken ends would increase in number."

Mr. Parrish's Tests showing the Influence of Humidity and Temperature Upon Power.

Mr. Wm. F. Parrish, Jr., Yorkhouse, London, England, has made some tests that are reproduced here in part as pertinent to this subject:

"One of the great influencing factors upon the power of a mill is the temperature. It is the effect of this that makes a mill start up hard in the morning, especially on Monday. The reason is improper lubrication, largely affected by temperature, with the further influence of relative humidity.

"Upon a single ring spinning frame the effect of humidity far out-values that of temperature. A test was made upon a frame of old Sawyer spindles, which are lubricated similarly to mule spindles, where temperature readings were taken every fifteen minutes from 7 a. m. until 4:45 p. m. The day was one of those known in America as "dog days." which occur in August, and during which peculiar feats are performed by both the temperature and the relative humidity.

"(From 8:15 a. m. to 3 p. m.)

Temperature increased,	12.5°
Relative humidity increased,	13.0%
Power increased,	8.2%

"(Another day's showing.)

Temperature increased,	10.0°
Relative humidity decreased,	7.0%
Horse Power decreased	8.7%

"Temperature increase can be considered as being practically the same in both tests.

"(Another peculiar test.)

Temperature decreased	5.6°
Humidity increased,	12.1%
Horse Power decreased,	5.0%

"This is exactly opposite to what the opinion of mill men and all of our previous experience would lead us to believe. The 480 cards taken during the three days of test were carefully checked, and the areas were found to compare exactly with the admission, pressure and point of cut-off. This last observation was the one that allowed us to solve the difficulty. The engine was well loaded, the main driving belt not being sufficiently large to carry more than an ordinary load on a normal day, and the increase of relative humidity of 12.1% added to the power required by the spinning frames so that the belt slip increased to such a point that the engine did not

transmit over 95% of the power it would have given under normal conditions.

Mr. Paine Upon the Increase of Power Required at High Humidities.

Mr. Sidney B. Paine, of the General Electric Company, has called attention to the surprising effect of high humidities in increasing the power consumption of frames fitted with individual motors; also to the effect of lubrication upon power consumption and especially in starting up mornings when the rooms have been allowed to cool down over night and the oil has become heavy and viscous. His observations confirm those of others, who have made a study of the subject.

Humidity and Temperature as Affecting Power.

This subject is deserving of more attention than it has yet received, even though many mill men have given it considerable study and thought. It has heretofore been difficult to maintain and control the proper conditions for these tests; but now with my regulators it is possible to make the proper investigations, which indeed are under way and the results of which will be published in Chapter VII.

Atmospheric Electricity in Factories.

The friction of machinery, the friction of moving belts, and many of the operations carried on in manufacturing establishments, generate static electricity. Dry air is a poor conductor of electricity, and moist air is a good conductor; in a dry atmosphere, therefore, electricity accumulates until everything is heavily charged with it, so that there is a strong tendency upon the part of dust and other minute particles and the individual fibres or materials in process of manufacture, to disengage themselves and fly off into the atmosphere.

This effect can be greatly lessened by either collecting the static electricity and conducting it away or by dissipating it; various devices are on the market for collecting and conducting away the static electricity but are only fairly successful and require some skill and attention, whereas simply the presence of a moderate amount of moisture in the air causes the electricity to discharge and dissipate itself.

Effect of Moisture in the Air upon Dust and "Fly".

The ill effect of dust and "fly" in the atmosphere upon the health of persons who breathe it is too generally conceded to require argument. The amount of waste made as "fly" is not generally appreciated, however, nor is the extent of the effect of "fly" on the appearance of yarn generally realized; in fine spinning or fine knitting, "fly" is particularly objectionable. It is not amiss therefore to point out that artificial humidity lessens the extent and amount of it very ma-

terially; that is to say, the mere presence of a normal amount of moisture in the air acts as a preventative to the extent of 54% as compared to the dry atmosphere that ordinarily exists in a mill without means for artificially moistening the air,—so an English commission found in 1889 after an exhaustive series of tests.

Advantages of Proper Atmospheric Conditions in Textile Manufacture.

In general, proper humidity and temperature uniformly maintained in manufacturing lessen both "visible" and "invisible waste;" increase the production in all departments; lessen power consumption; and, the output is a stronger, heavier and better looking product than if manufactured under unfavorable atmospheric conditions.

Whatever the textile fibre may be, it is in its most favorable condition for manufacturing, as regards strength, adaptability and appearance.

Differences in the amounts of moisture in the raw material are equalized, resulting in a product of exceeding uniformity in weight,—the materials that are too dry or too wet absorbing or losing moisture as the case may be until they are in equilibrium with the atmosphere maintained in the mill.

Closer adjustments of machinery can be made and maintained to obvious advantage.

Frictional electricity generated by the machinery, the belting and the stock in process, is dissipated and practically eliminated.

The natural moisture of the fibre is retained, and the saving in "invisible waste" so large as to startle manufacturers who investigate it,—it being no uncommon thing in cotton mills that two and even three or four per cent. of moisture is fanned out of the stock in manufacture and charged up as "invisible waste," when it might just as well be retained, to the benefit of the purchaser as well as the seller.

The lesser amount of "visible waste" due to fewer broken ends, lesser singling and lapping up, fewer thick and thin places in materials and lesser similar troubles,—what all these amount to, is better understood and appreciated, however, because they are easier to identify and actually to take into account.

It is not to be lost sight of that less "seconds" are made when the various troubles above mentioned are reduced to a minimum.

Nor does it admit of argument that in a better and more wholesome atmosphere the increased mental and physical activities of the operatives will show in increased output and in better work.

And finally, it is to be borne in mind that a "properly conditioned atmosphere" means one in which both humidity and

temperature are controlled, and maintained to the predetermined standard found best for the particular work in hand.

In Carding.

In Spinning.

In Weaving.

In Knitting.

In carding, dry atmospheric conditions not only cause the formation and collection of electricity with the attendant difficulty in manipulation of the stock, but the fibres are weakened, brittle and wiry. In combing, the result of those conditions is more disastrous; in fact, good combing absolutely demands the proper humidity. In drawing, the bad effects are less but still noticeable. In roving, a uniform humidity is necessary to maintain the uniform tension so desirable.

In spinning, the breaking strength can only be maintained by a proper amount of moisture in the air; the effect of changeable atmospheric conditions on the spindle bands is not only to increase the power required to drive, due to increased band pull and traveller pull, but also to cause loss of production and great variations in twist; a close approximation of the counts or numbers spun is possible only with uniformly maintained humidity; and finally the difference in the character and appearance of the yarn alone is worth the expense of an air moistening outfit,—a smoother, softer and more level yarn, freedom from harshness and kinks, less knots, etc.

In weaving, all the defects inherited from the spinner are magnified in the cloth. But even assuming that good yarns come to the weave room, slashed warps demand a moist atmosphere for best working in direct proportion to the amount of sizing to which they have been subjected. Uniform atmospheric conditions here also greatly lessen the loom fixer's work with its resulting cost and loss of production. A softer twist filling can be woven giving a better "feel" to the cloth.

In knitting, especialy fine work, uniform humidity and freedom from "fly" are now considered well worth the cost of equipment and maintenance for that purpose.

And finally, whether the product to be marketed is yarn, cloth or knit goods, the mills themselves will get the "regain" on their own stuff, that otherwise goes to the finisher, to the consumer, or to both.

*Humidity in Textile Mills.

(*Reprinted from Textile World Record, February,* 1908.)

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"The humidity of the air has an important influence on the cotton fibre in the processes of manufacturing.

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*This article has already been reproduced in part on pages 1339-1342.

'I have not been able to find any tests of unsized or sized yarns in sufficient detail to satisfy me, and as such tests require special apparatus I, therefore, requested Mr. W. F. Whittaker of Darwen, a County Council scholar, now at the Manchester School of Technology, to make several series of tests for me.

'A balance was arranged with the weighing pan inside a drying oven, while the other pan was outside. It was thus possible to do the weighing without removing the yarn from the oven.

'A single thread testing machine made by H. Baer & Co., Zurich, was used to ascertain, the breaking strain and the length of stretch with gradually decreasing amounts of moisture. The length of yarn tested in each case was 18 inches.

'The length of stretch is the distance the yarn elongates from the commencement of the test until it breaks.'

Summary of the Tests of Unsized Yarn. Counts 24.7.

Percentage of Moisture	Breaking strain in ounces	Length of stretch in inches	Loss of strength	Loss of stretch
6.48	6.435	1.087	....%	....%
4.41	5.0	.772	22.3%	28.8%
2.39	4.775	.681	25.8%	37.4%
.45	4.78	.65	25.7%	40.2%
Dry	4.215	.625	34.5%	42.5%

Summary of the Tests on 36s Yarn Sized with 16.5 per cent. of Size.

10.18	7.225	.65	....%	....%
8.02	6.55	.569	9.4%	12.6%
5.94	5.925	.4625	18.0%	28.8%
3.94	5.985	.412	17.2%	36.6%
2.02	6.09	.369	15.8%	43.1%
Dry	4.77	.288	34.	55.7%

"The two summaries clearly show that there is a decided decrease in the "strength" and "stretch" of yarn as the percentage of moisture decreases.

"The percentages of moisture given in this extract are based on the dry weight of the cotton and must not be confused with the percentage of humidity in the air. They illustrate, however, the advantage of moisture in the air of cotton mills because the presence of moisture in the air necessarily means its presence in the cotton.

* * * * * * * * *

"On one point there can be little chance for dispute, namely, the need for regulating the moisture in mills. Such regulation is of importance not only for the protection of the operatives, but as affecting the efficiency of the mill as regards both the quality of the work and the amount of production.

* * * * * * * * *

"It is difficult to lay too much emphasis on the importance of careful scientific methods in this process of air moistening. The health of the operatives and the efficiency of the mill are involved to a very considerable extent. In spite of these facts the subject is but imperfectly understood by manufacturers; in many mills no attempt is made to study and regulate the moistening of the air in order to protect the operative and obtain the best results; no general rule or standard is accepted by the mills; and the mill manager who realizes the importance of the process and seeks intelligently to determine the facts is the exception to the rule."

IV.

Regain and Hartshorne's Tables

***Physical Characteristics of Textile Fibres.**

A consideration of the hygroscopic properties of any fibre carries with it an examination into its physical structure. Briefly stated textile fibres are of animal, vegetable, mineral or artificial origin. The most important animal fibres are wool and silk; the most important vegetable fibres are cotton and linen. For the purposes of this article mineral and artificial fibres may be neglected.

Whereas all textile fibres have much in common, a few observations upon the individual peculiarities of each are in order, notwithstanding the fact that these volumes pertain more directly to cotton manufacturing than to that of the other fibres.

Wool.

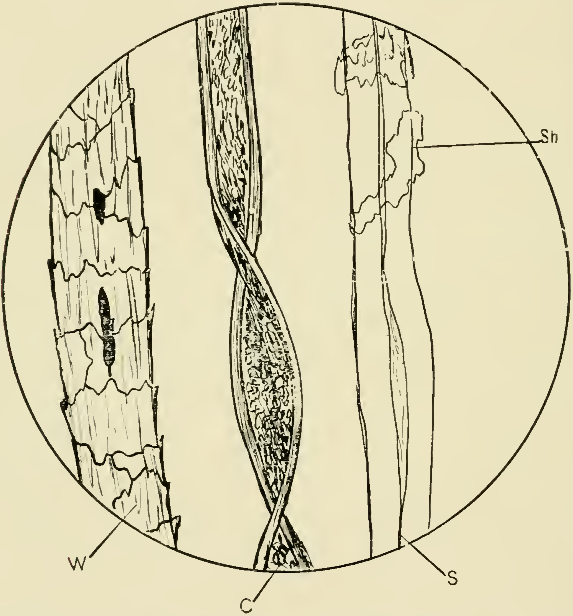
Of that of the wool bearing animals, the wool of the sheep is the best known. Wool, or any hair fibre, is an organized growth starting from a root in the skin designated a hair follicle; its structure comprises layers of animal cells of various forms and in different arrangements. The hair follicle is the base of supply not only constructively, but for supplies such as the oil which is supplied to the fibre thereby giving it pliability and elasticity. In addition to this oil within the fibre itself, a fatty and waxy substance known as wool fat is excreted from the sebaceous glands in the skin, from which it gradually coats the fibres in the nature of a protective covering. The oil and grease above described with the dirt collected therein is removed in the preparation of wool for manufacture, by a process known as wool scouring or washing. This oil and grease may be considered superficial, however, for there still remains in the cells themselves a wool oil that must be retained that the fibre may not lose its natural resilience. The structure of the wool fibre consists of three distinct layers: an internal cellular part containing the coloring matter, a layer of cellular fibres which give it its strength and elasticity, and an outer layer or epidermis of horn-like tissues consisting of overlapping scales. This epidermal scaly covering is characteristic of wool and can readily be distinguished with a microscope. The scales are translucent in appearance, their exact size and shape varying considerably with different varieties of wool. From the above description of the structure of the wool fibre itself and of the treatment it receives

*See next page.

in scouring and washing, one is quite prepared to learn of its extraordinary hygroscopic quality, which greatly exceeds that of all the other fibres.

Silk.

The silk fibre differs from all the other fibres insomuch that it is a continuous thread, spun by the silk worm. Without going into further details, it may be briefly stated that in the raw state the fibre consists of a double thread cemented together by a glue-like substance

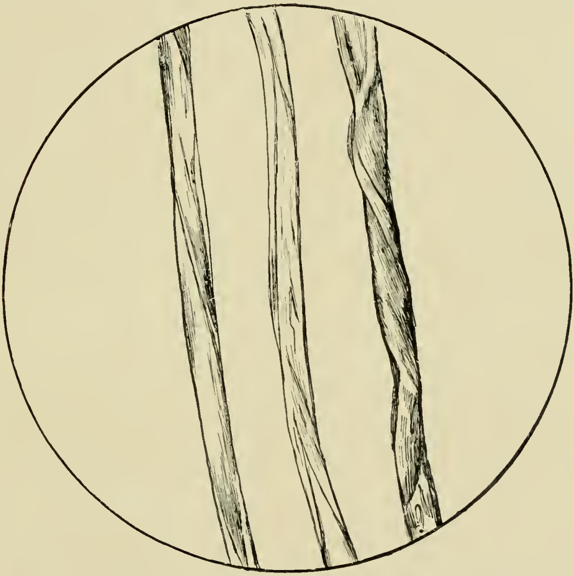


(Micrograph by Mathews, showing comparison of wool, silk and cotton fibres x 500. W represents a wool fibre, showing marking of scales; C, cotton, showing twisted ribbon-like structure; and S, silk, showing double strand and shreds of silk glue, sh.)

and is of a yellowish translucent appearance. Under the microscope, the raw silk fibre is seen to consist of an inner fibre of fibroin, as it is termed, covered by a layer of the sericin, or silk-glue; like wool, the silk fibre is prepared for manufacture by being boiled or scoured so that the double threads are separated and the silk-glue removed. The fibre then appears as a single nearly white lustrous fibre, apparently a continuous filament but probably a bundle of exceedingly minute fibrils. Hygroscopically silk is second only to wool.

Cotton.

Cotton belongs to the species of vegetable fibre known as single cell plant hairs. Each cotton fibre is a single cell with one end closed and the other end attached to a seed. The cell walls have no definite structure and are porous. In the early stages of its growth the cotton fibre is round and cylindrical with a central canal extending through it filled with juices; in the ripening process, the cotton boll first opens exposing the fibres to light and air, the juices in the canal dry up and deposit themselves



(Micrograph by Mathews, showing tne stretching and straighte ing-out effect of mercerizing cotton x 350.)

unequally in proportion to the amount of exposure, thereby causing an unequal collapse and contraction of the cell walls, resulting in the twisting of each fibre, so characteristically peculiar to cotton. "Neps" are short fibres mixed in with the others, and to some extent, therefore, their presence cannot be helped; at the same time the percentage of them is often unnecessarily increased by excessive breakage of fibre through bad handling and manipulation under unfavorable atmospheric conditions in the processes of carding and spinning. Each cotton fibre consists of a cell wall of pure cellulose covered by an external cuticular fibre of modified cellulose,

and an internal lining to the central canal somewhat like the outer coating—the whole fibre being surrounded at intervals by ligatures or ties binding and holding the structure together, with a thin waxy coating covering all. The flattened ribbon-like, unequally twisted fibre with irregular edges readily differentiates cotton from all other fibres. The part that the twist of cotton fibre plays in manufacturing cannot be over-estimated. This twist is by no means either continuous in one direction or the other, nor is it regular in pitch; parts of the same fibre may be even flat and more or less straight. Fortunately, however, in the same lot of cotton there is enough similarity and regularity in the conformation and dimension of the individual fibres, that a proper selection can be made to great advantage for spinning. The spinning qualities of any lot of cotton depend largely upon the regularity and uniformity of the twist of the individual fibres, upon the length and fineness of the staple and upon the extent to which the volatile constituents of the wax have been dried out by age. Cotton and linen are nearly equally hygroscopic, and are much less so than wool or silk.

Linen.

Linen is obtained from the flax plant, by a process called "retting." It belongs to the species of vegetable fibres known as bast fibres. Cellulose is the basis of all vegetable fibres, and bast fibre consists of bundles of cellulose cells, each of which is a completely enclosed tube, pointed at each end. The cells are long and usually polygonal in cross section. After reaching its proper growth the flax plant is treated by a process known as "rippling," which removes the seeds and leaves. The stalks are then placed in water to decompose by fermentation, after which the tissues are easily removed and the linen fibres separated. As already stated, this process is called "retting." Linen fibres are rather long with regular structure apparently round but somewhat polygonal in cross section with a peculiarity at regular intervals in the way of faintly marked dislocations in the shape of a letter "X," like joints as it were. The oil and wax constituents in the flax fibre contribute to its spinning quality and great care must, therefore, be taken in this retting process that the linen fibre resulting shall not be deficient in those constituents. In hygroscopic quality linen is about the same as cotton.

Water of Hydration in Fibres.

The moisture contained in fibres is unquestionably of two kinds; one kind in which it undoubtedly exists in chemical combination with the fibre and known as the water of hydration; and another kind the presence of which is due entirely to the hygroscopic quality of the fibre, and which exists in irregular and variable amounts in proportion to

changes in the humidity and temperature of the air to which it is exposed. The water of hydration is not, however, capable of being driven off until sufficient heat has been applied to accomplish a complete or partial destruction of the fibre. Therefore, in considering regain, only hygroscopic moisture is taken into account.

Effects of Hygroscopic Moisture upon the Physical Structure of Fibres.

In the first place all dry fibres are poor conductors of electricity and are therefore easily susceptible to being so electrically charged as to render manipulation difficult; whereas, the presence of moisture in fibres renders them good conductors of electricity, so that there is no tendency for them to become charged with static electricity. It is further to be noted that oil in fibres either existing naturally or artificially applied renders them particularly bad conductors of electricity; such fibres in particular being difficult to manipulate without proper moisture.

Under another heading will be given the amounts of hygroscopic moisture, or "regain," usually considered allowable in the different kinds of fibres. That these amounts should differ greatly in wool, silk, linen and cotton is self-evident considering the differences in their structure and the methods of their preparation. As would also be expected the time element is different for each of these fibres; in other words, some of them pick up moisture and lose moisture more rapidly in the same length of time than others: that is, of course, due to the greater or less obstruction offered to the passage of the vapor of the air into and out of the fibres.

That considerable of the interchange of moisture from the air to the fibre and vice versa is due to capillary attraction there is no doubt; this is particularly the case where there are interstices as in the case of wool and linen, pores as in the case of cotton, and more or less hollow longitudinal canals as in the case of almost all fibres.

Yet this does not account for all the moisture, in either amount or quickness of change by any means; the silk fibre in particular illustrates this point. In the same way that metabolic changes occur in which gases pass through separating membranes from one side to another, moisture in the form of vapor undoubtedly passes in and out of the fibre cells.

While the effect of the presence of more or less moisture varies with the different fibres, the effect is quite marked in all of them. It is most discernible, however, in the case of the cotton fibre, on account of its effect on the twist of the fibre.

That the addition of moisture in all fibres adds weight, pliability, elasticity and flexibility goes without saying. And also that the presence of an excessive amount of moisture will render them heavy and inert is equally true.

From all of which, it is evident that there is a standard of best conditions, and of theoretically normal conditions, for all fibres at which they would not only be at their best from a manufacturing standpoint, but also at which they would most nearly coincide in weight with the actual conditions under which they would be found to exist under average conditions of atmospheric temperature and humidity.

Regain.

And so the subject of regain is one of the greatest importance to manufacturers, and a definite standard of regain is a matter of extreme desirability. Until comparatively recently the use of the word "regain" suggested both to the technologist and the manufacturer only the idea of a fixed and agreed-upon standard of moisture in textiles devised for the purposes of equity and fairness in commercial trade relations. This condition was brought about by the wide variations in shipping and receiving weights of textile materials, particularly of wool and silk, which were not only exceedingly hygroscopic, but also of considerable value. And so, in Europe one finds conditioning houses established for the purpose of definitely ascertaining the actual amount of fibre and moisture present in any given lot of textile material submitted to them for inspection, and who will furnish a certificate with the true or settling weight for the transaction based on the accepted standard percentage of moisture or "regain." In these conditioning houses the process of determining the amount of moisture present is termed "conditioning,"—a misnomer and a very unfortunate one at that, for the proper use of the word clearly should be to designate the mechanical function of either artificially adding or subtracting moisture and heat to the atmosphere, the textile materials exposed to it, or the direct moistening of such materials by actual contact.

Briefly the process is as follows: Samples are carefully selected for testing so as to represent an average of the lot submitted; after being carefully weighed the samples are dried in a conditioning oven to a constant weight at a temperature of 105° to 110° Centigrade or about 220° Fahrenheit, which is a little above the boiling point of water. The difference between the original weight and the resultant oven-dried weight represents the amount of moisture the material contains; the oven-dried weight is taken as the datum point and to it is added a certain amount termed "regain" to bring it up to the accepted standard. At Bradford, England, the center of the wool industry in England, the following standards of regain are official and accepted:

Wools and waste	16	per cent.
Tops combed with oil	19	" "
Tops combed without oil	18¼	" "
Ordinary noils	14	" "

Clean noils	16	per cent.
Yarns, worsted	18¼	" "
Yarns, cotton	8½	" "
Yarns, silk	11	" "
Cloths, worsted and woolen	16	" "

The system of conditioning adopted at Bradford is as follows: The weights of the packages and conditions are taken by three persons independently on sensitive scales which are adjusted weekly. These scales have a weighing capacity from one-half pound to ten tons. In making the tests for moisture, the samples are carefully selected from various parts of the packages. The amount of the material taken for this purpose is for wools, noils, and wastes, about two pounds from each package; for tops, three balls; for yarns in hank, about four pounds in 1200 pounds; for yarns on bobbins or tubes, twenty to forty bobbins or tubes, and for yarns on cones, cheeses, etc., five to fifteen pounds.

At Roubaix, in France, the accepted standard is as follows:

Wools	14¼	per cent.
Tops	18¼	" "
Woolen yarns	17	" "

The International Congress at Turin in 1895 fixed the amount of regain as follows:

Silk	11	per cent.
Wool (tops)	18¼	" "
Wool (yarn)	17	" "
Cotton	8½	" "
Linen	12	" "
Hemp	12	" "
Jute	13¾	" "
New Zealand Hemp	13¾	" "

In the United States no definite standard of regain has ever been agreed upon or accepted, each private establishment fixing a standard for itself, or having none at all. The difference in amounts of percentage permissible in different localities is explained by the fact that in each case it was desired to hit upon such a standard that if the different textile materials were exposed to the average atmospheric conditions of the place, that the accepted standards would be those at which the fibres would be in what may be said to be hygroscopic equilibrium with the atmosphere, neither gaining nor losing weight. But while this theoretical conception is a logical choice and supplies the demand for a basis of settlement in trade relations, in actual practice tests must necessarily be made and corrections applied, for atmospheric conditions at all times are not average conditions by any means.

The method of testing samples has already been described. The oven in which the drying to a constant weight is conducted is a very simple affair, consisting of a shell or stove-like exterior, with means inside for heating, and a thermometer inserted at a suitable point for registering the temperature. Above the oven is a delicate balance suitably enclosed and protected from drafts with a scale pan on one side for weights and a wire support on the other side extending down into the oven through a hole in the top, on the lower end of the wire the test sample being supported in a wire basket.

Regain and Conditioning Calculations.

Obviously the more important calculations for this work involve,—

(1) A determination of the percentage of moisture in the material submitted for examination.

(2) And the subsequent determination of the "conditioned" weight of the material to bring it to a definite and accepted percentage of regain.

The following are formulas for the solution of the problems involved in conditioning. From those, numbers of others can be derived by which any problem connected with this subject can be solved. These formulas were, I believe, worked out by Persoz and published by him in his *Essai des Matieres Textiles.*

(1) If a weight (w) of material after drying shows a weight (a), what percentage (x) of moisture does it contain?

w—a=loss in weight on drying=moisture.

$$\frac{W-a}{w} \times 100 = x, \text{ per cent. of moisture.}$$

(2) If a quantity of material of weight (w) contains (x) per cent. of moisture, what is its dry weight (a)?

$$a = w\left(1-\frac{x}{100}\right).$$

(3) If from a weight (W)of material there is taken a sample of weight (w) and the dried weight of this is found to be (a), what will be the conditioned weight (C) of the material allowing a regain of (R) per cent?

The dry weight (A) of the entire material will be

$$A = W \times \frac{a}{w},$$

and the conditioned weight will be

$$C = W \times \frac{a}{w}\left(1+\frac{R}{100}\right).$$

(4) A substance is conditioned with a regain of (R) per cent., what percentage of moisture (x) does it contain?

We have the proportion

$$\frac{100 + R}{R} = \frac{100}{x};$$

therefore

$$x = \frac{100\,R}{100 + R}.$$

The following table shows the percentage of moisture in any material corresponding to a definite percentage of regain.

Per Cent. Regain	Per Cent. of Moisture	Per Cent. Regain	Per Cent. of Moisture
5	4.76	12	10.71
6	5.66	12.5	11.11
7	6.54	13	11.50
7.5	6.98	14	12.28
8	7.41	15	13.04
8.5	7.83	16	13.79
9	8.26	17	14.53
10	9.09	18	15.25
11	9.91	19	15.97
		20	16.67

(5) If a material contains (x) per cent. of moisture, what will be the corresponding percentage of regain (R)?

This is the reverse of the previous problem. We have

$$R = \frac{100x}{100 - x}.$$

The following table shows the percentage of regain of any material corresponding to a definite percentage of moisture.

Per Cent. of Moisture	Per Cent. Regain	Per Cent. of Moisture	Per Cent. Regain
5	5.26	13	14.94
6	6.38	14	16.28
7	7.53	15	17.65
8	8.70	16	19.05
9	9.89	17	20.48
10	11.11	18	21.95
11	12.36	19	23.46
12	13.64	20	25.00

(6) If a material is required to possess a definite conditioned weight (C), what percentage of regain (R) must be applied to the dry weight (a)?

We have the proportion

$$\frac{a}{C-a}=\frac{100}{R};$$

therefore

$$R=100\,\frac{C-a}{a}.$$

(7) If the dry weight (a) of any material is given, what quantity of water (q) would it have to absorb in order to contain (x) per cent.?

We have the proportion

$$\frac{100-x}{x}=\frac{a}{q};$$

therefore

$$q=\frac{ax}{100-x}.$$

The weight (W) of the material after absorbing the moisture would be

$$a+q.$$

or

$$W=\frac{100a}{100-x}.$$

(8) If the dry weight (a) of a material is given, what would be its conditioned weight (C), allowing (R) percentage of regain?

We have in this case

$$C=a\left(\frac{1+R}{100}\right).$$

(9) If the conditioned weight (C) of a material is given with a percentage of regain (R), what is its dry weight (a)?

$$a=\frac{100C}{100+R}.$$

(10) If the percentage of moisture (x) is known in a material, what will be the conditioned weight (C), allowing a regain of (R) per cent.?

The dry weight (a) will be

$$a\left(1-\frac{x}{100}\right).$$

Some Comparative Data on Moisture in Cotton and Worsteds.

(Hartshorne.)

Hartshorne on Regain.

A few years ago Mr. W. D. Hartshorne of the Arlington Mills, at Lawrence, Mass., not only made a thorough examination into the subject of regain but kept records of his observations and published them in a paper read before the New England Cotton Manufacturers Association at their Atlantic City meeting in September 1905; Mr. Hartshorne's paper is entitled "Some Comparative Data on Moisture in Cotton and Worsted." By permission, I herewith append extracts from his paper as follows:

* * * * * * * * *

"Theoretically, it makes absolutely no difference whether the standard condition of regain be assumed at one figure or another, provided, only that the actual condition is known, and that some standard has been agreed upon between the buyer and the seller. Practically, however, it is desirable that the standard condition should be somewhere near the average which may be expected for the country or countries within whose borders the transaction takes place, and that at the time of delivery the material shall be in its whole mass as near as may be in this state of condition. If this were not so it would be difficult to accurately allow to the satisfaction of both parties, for the changes in weight which might readily take place while in transit, or upon the least exposure.

"The inside of a mill, particularly in the winter time, unless artificially provided with moisture, will have a relative humidity much less than the outside air, and stock running in such a mill, not so provided, will lose moisture. If shipped in this state a proper allowance must necessarily be made by the seller, either in his weight or in his price, or he will be cheating either himself or his purchaser. *To a mill which weaves its own spinning and sells its product by the yard, the subject may seem of little or no importance from a commercial point of view, but even here the knowledge of what constitutes the best working conditions and what degree of atmospheric humidity for a given temperature will give the best results, may be of great importance.*

"About ten years ago I began collecting data to determine if possible the average natural condition of worsted yarn in this country or, to speak more accurately, what this condition was for the neighborhood of Lawrence, Massachusetts.* The general impression had seemed to be that for our climate

*See "Tops: A new American Industry," published by the Arlington Mills, Riverside Press, 1898.

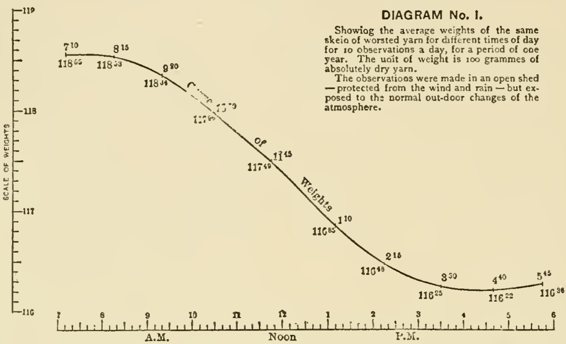


DIAGRAM No. I.

Showing the average weights of the same skein of worsted yarn for different times of day for 10 observations a day, for a period of one year. The unit of weight is 100 grammes of absolutely dry yarn.

The observations were made in an open shed — protected from the wind and rain — but exposed to the normal out-door changes of the atmosphere.

a difference of from two to three per cent. would be expected between this country and England or the Continent, and for our newly developing Top business a basis of 15 per cent. regain had already been assumed as probably a safe standard; but it seemed best to establish what it ought to be with some degree of certainty. With this object in view, a skein of worsted yarn was prepared whose absolutely dry weight was carefully determined by weighing and testing other skeins of the same material under exactly like conditions. This skein was then hung up in an open shed, protected from the sun and rain, but with good ventilation, so that it could be considered as fairly representing the outdoor conditions. Its weight was then carefully taken and recorded ten times a day, at approximately equal intervals, for every day in the year except Sundays and holidays, for a period of one year from May 1, 1895. A record was also kept of the temperature and relative humidity, as obtained from the readings of a set of wet and dry bulb thermometers, located within a few feet of this skein, and taken at the time of each weighing, except for a short time in the winter, when the humidity observations were omitted owing to the difficulty of obtaining them accurately at low temperatures.

"The variations in the weight of this skein were remarkable, ranging from a little over 7 per cent. to as high as 35 per cent. on the original dry weight. There were occasional variations of 15 or even 19 per cent. in 24 hours. An analysis of the observations will be found in the appendix.

"It is interesting to observe that aside from the temporary extreme changes there seemed to be a fairly regular diurnal variation from morning to afternoon, being generally greater

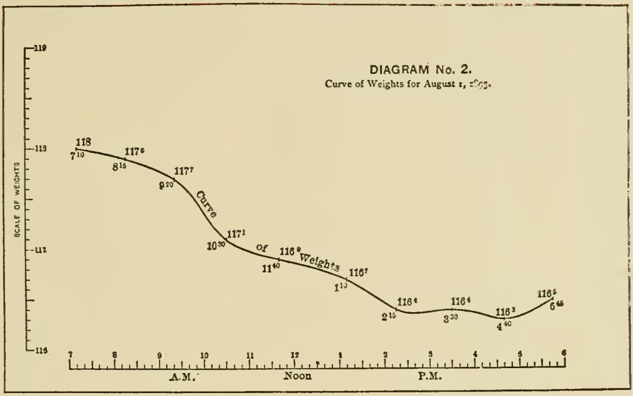
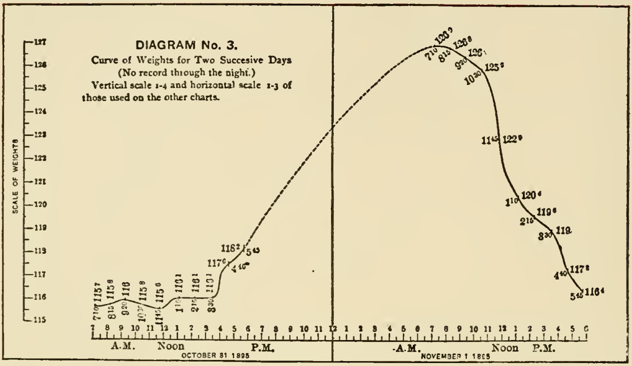


DIAGRAM No. 2.
Curve of Weights for August 1, 1905.

in the morning and less in the afternoon. This may perhaps, be best exemplified by the curve in diagram, No. 1, representing the average of the daily weighings of this skein for each respective hour named thereon throughout the year. The weights as given are on the basis of 100 parts for the absolutely dry weight, so that the regain percentage is at once shown. It will be seen from this diagram that on the average there was for that year at least, and for this skein of yarn (2/42 Australian, combed in oil, and spun on the Bradford system) a difference of about 2¼ per cent. between 7.30 in the morning and 3.30 in the afternoon.

"A typical individual day is shown in diagram No. 2, and two successive days of marked variation are shown by diagram, No. 3. With the object of trying to trace the relationship between relative humidity, skein regain, and temperature, diagram No. 4, was plotted. As might have been expected, however, nothing definite was apparent, beyond the general fact that there seemed to be a correlation between humidity, temperature and skein regain, but the precise relationship was not disclosed, nor did such exact relationship appear to be discoverable from a long and careful study and comparison of the daily readings.

"As shown in the appendix, these observations gave for outdoor conditions a general average for the year of 17.45 per cent. or something less than the standard allowed abroad, and without attempting at the time to go further into the law of change, we felt that we had at least demonstrated that a standard of 15 per cent. regain for worsted, as had already been assumed, was conservative for this country. Since the promulgation of this standard by the Arlington



Mills in their regular business dealings in Tops, all other Top makers of this country have, I believe, adopted the same standard, and it may be said to be universally accepted by the trade in this country, so far as Tops are concerned, and its general acceptance on worsted yarn is, perhaps, only a matter of time. So far as I know, no effort has yet been made to adopt a standard for cotton in this country, though it is generally assumed that the standard should be about half that of worsted, or say 7½ per cent. (the foreign standard is 8½ per cent). This at any rate would be a convenient amount to figure for, and good reasons for its adoption may be made apparent later in this paper."

* * * * * * * * *

The Problem of Relationship.

"The determination of this exact relationship is a problem which I have had under investigation for some time. That the absorption of moisture by worsted yarn is in some manner dependent upon relative humidity and temperature was abundantly shown by the year of exterior observations recorded, and also by many interior records since then. It is possibly true that the barometric condition of the atmosphere affects the result but so far as this may be true its effect is so far over-shadowed by the element of temperature that for practical mill purposes the height of the barometer may, I believe, be neglected. At any rate, I have made no attempt to find such effect independent of the relative humidity. In fact, all observations which I have taken for either relative humidity or skein regain have been on the assumption that the barometer stood at practically 30 inches."

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"For the purpose of eliminating the effect of hard twist in retarding the absorption of moisture, and the effect of

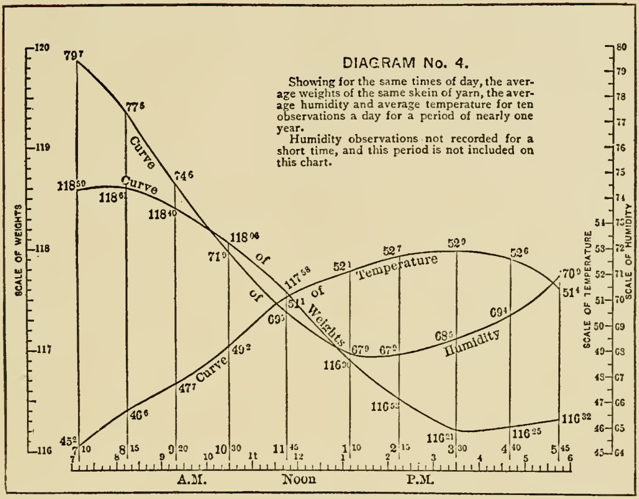


DIAGRAM No. 4.

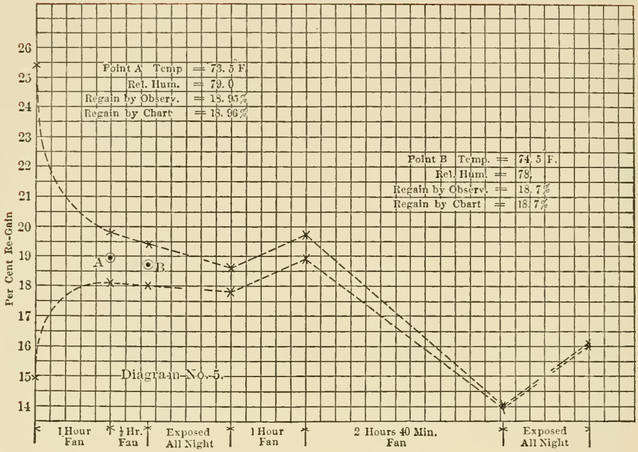
Showing for the same times of day, the average weights of the same skein of yarn, the average humidity and average temperature for ten observations a day for a period of nearly one year.

Humidity observations not recorded for a short time, and this period is not included on this chart.

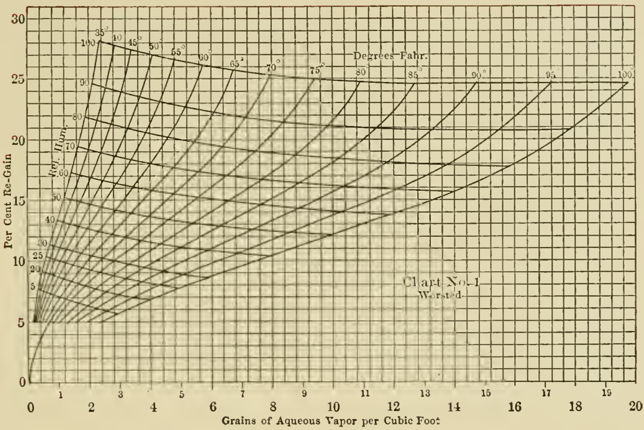
oil upon the net result,* a quantity of 2/24 soft twist, French spun, fine Australian yarn was prepared and extracted with ether, dried and extracted again with warm water, to which a few drops of ammonia had been added. After being allowed to remain hung up for some time, to come to its natural state, this yarn was made up into groups of skeins of the same length each, and of approximately the same weight. The final weight and moisture state of these skeins was carefully determined after being hung up together again for a period of about two days. The moisture state was determined by testing individual skeins of the different groups, by drying in the ordinary Bradford oven at a temperature of from 220 degrees to 230 degrees until they ceased to lose weight, and also by leaving small two gramme skeins in a weighing bottle, under a dessicator, and over strong sulphuric acid. These two methods were used to check each other from time to time during the experiments, to establish the true weight of the skeins which were being used as moisture indicators.

"Attention has already been called to what I have termed the 'lagging behind effect,' due to the necessary element of time required to take up or part with moisture by the skein,

*Experiments have proved that olive oil has no appreciable effect in preventing, though it may retard somewhat, the absorption of moisture, but the amount absorbed was strictly in proportion to the dry weight of the wool, and not to the weight of the wool and oil together, though for most purposes the percentage of oil being small it need not be considered.



the effect of which is to show for a given humidity and given temperature a higher result when the skein regain condition has been a falling one, and a lower result when that condition has been a rising one. In undertaking, therefore, a careful series of experiments it was deemed necessary to make the skeins to be examined small enough to be accurately weighed on a delicate balance, so that the amount of moisture which had to be absorbed or parted with by a given skein was so small in amount as not to require a great many cubic feet of air to supply or displace it. To insure rapid contact of moist or dry air with the skeins being tested a small electric fan was used. The moisture state of this air was carefully determined at the moment the sample skeins were inclosed in their weighing bottles, generally by the Sling Hygrometer, but when circumstances did not permit of this resort was had to Daniels' Dew Point Hygrometer. Upon comparing the results obtained from two skeins hung together, one of which had previously been exposed to a damp atmosphere, and the other to a comparatively dry atmosphere, it was soon found that while it might require hours, or even days, to bring the skeins exactly together again the mean between the two at any time after fifteen or twenty minutes particularly if still converging was closely the same for the same temperature and the same relative humidity, and equal to what a third skein would show which had been a long time exposed to identical conditions. It was, therefore, assumed that this mean could be relied upon to quickly determine the true regain relationship



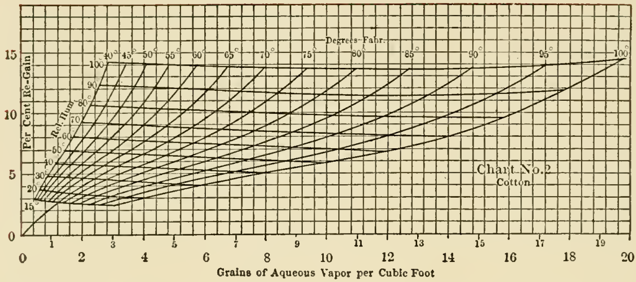
for any not too rapidly changing conditions. We were thus able to make use of the very lagging behind effect, which had previously rendered individual observations seemingly incompatible to establish comparatively accurate and true results. Diagram No. 5 is intended to illustrate this lagging behind and coming together effect, and the method of obtaining quick results.

"In order to compare the results obtained by this method, resort has been had to what is believed to be a new form of charting,* shown in Chart No. 1 for worsted and Chart No. 2 for cotton, on a scale greatly reduced from the original where the vertical distances represent the per cent. of regain in the skein, and the horizontal distances the grains of moisture per cubic foot of space for the temperature and relative humidity found and shown upon the chart. It will be observed that the lines joining points of the same relative humidity (for example the 50 per cent. line) cross the isothermal lines in a generally oblique direction, curved slightly convex on the downward side. That is to say, that for a given relative humidity the regain is less at the higher temperatures, but not less in a constant ratio.

"By the aid of this charting principle a sufficient number of points have been located to trace the isothermal and the relative humidity lines shown, and from these charted results it has been found possible to tabulate** by interpolation the

*For this form of charting I am indebted to the ingenuity of Mr. Richard P. Iddings, Chemist at the Arlington Mills, by whom also all the observations used in constructing the charts were made.

**The tables for both worsted and cotton yarns will be found appended.



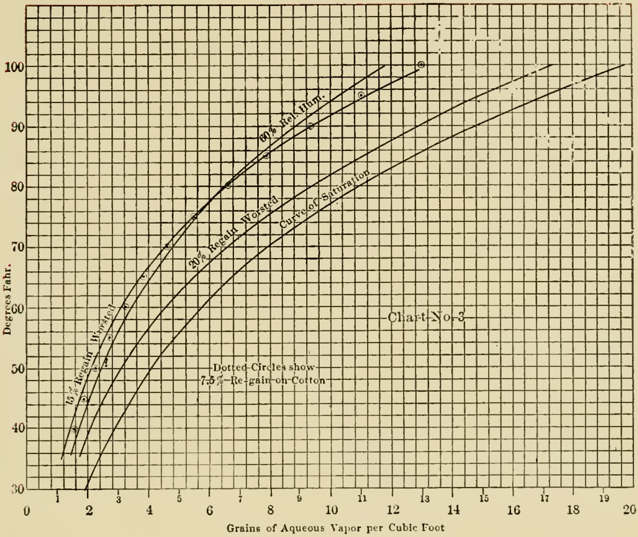
per cent. of regain on worsted with a fair degree of accuracy for each per cent. of relative humidity from 15 per cent. up to saturation and for isothermals 5 degrees of temperature apart from 35 degrees Fahrenheit to 100 degrees Fahrenheit.

"The data for securing the cotton chart are not by any means so complete as those used for the worsted chart, and, therefore, I cannot claim for it the same degree of accuracy. It is probably, however, near enough for practical purposes.

"It will be clearly seen from these charts that the regain per cents. for cotton are approximately one-half those for worsted under like conditions, but the relative humidity lines are more nearly straight and, therefore, bear a more nearly constant ratio to the regain.

"Another method of comparing results is shown in Chart No. 3 where the vertical co-ordinates represent degrees of temperature (Fahrenheit scale) and the horizontal co-ordinates the weight in grains of aqueous vapor per cubic foot. I have represented here the curve of saturation or 100 per cent. of humidity and the curve of 60 per cent. relative humidity in comparison with the curve of 15 per cent. regain in worsted, and (to avoid confusion) a number of points only on the curve of 7½ per cent. regain in cotton. An additional regain curve of 20 per cent in worsted is also shown. It will be noticed here that at ordinary mill temperatures, the 7½ per cent. cotton curve closely coincides with the 15 per cent. worsted curve, and within the limits of observation their deviation from each other is not great at either high or low temperatures. This fact may be taken, therefore, as a good reason for establishing the 7½ per cent. regain for cotton, if it be conceded that 15 per cent. is the proper standard for worsted.

"It is interesting to note also that the 60 per cent. humidity curve crosses the combined regain curve, just named, at about 77 degrees Fahrenheit, a room condition which, according to Sconfietti, is compatible with both good work and comfort in a cotton spinning room.



"Sconfietti* gives his own experience, as corroborating that of other men, that the most favorable temperature for manufacturing cotton (and other textile fibres in general) is between 20 degrees and 25 degrees Centigrade (68 and 77 degrees Fahrenheit) while the relative humidity for cotton should be:—

In Carding	between	50 and 55	per cent.
" Spinning	"	55 and 60	"
" Weaving	"	65 and 70	"

"These figures would indicate a regain condition in cotton:—

In Carding	of from about	6.5	per cent.	to	7.2	per cent.
" Spinning	" " "	6.9	"	" "	7.7	"
" Weaving	" " "	8.1	"	" "	8.8	"

or in other words, that for cotton the stock should be GAINING at each step in the manufacture.

"It would be interesting to know if this has been found to be true by members of this Association. Whether this be true or not for cotton, I am sure that it is not true for worsted, so far as the Bradford system of spinning is concerned. For the Bradford system of spinning, where the stock contains oil, there seems to be no doubt that it must be LOSING moisture during the process of spinning to make a good spin, hence the necessity, if the top contains only 15 per

*An interesting and instructive paper "The Humidification and Cooling of Textile Mills," by Leopold Sconfietti, reprinted from the Textile Manufacturer, 1903.

cent. regain, for keeping the moisture condition well up during the processes of drawing and roving or else for long ageing in a cool, damp cellar before going to the spinning frame. The latter plan used to be thought an absolute necessity, but which modern successes in humidification have very largely obviated."

Analysis of Observations.

	Lowest Day		Highest Day		Lowest Observation		Highest Observation		Greatest Difference in Twenty-four Hours	
	%		%		%		%		%	
May	11^{60}	17th	21^{50}	27th	9^{7}	17th	22^{0}	6th and 27th	8^{2}	6th to 7th
June	13^{01}	19th	25^{92}	29th	10^{7}	14th	27^{5}	28th	10^{0}	5th to 6th
July	14^{95}	25th	23^{96}	17th	12^{9}	3rd	26^{6}	1st	9^{1}	1st to 2d
August	14^{45}	9th	22^{00}	13th	12^{6}	21st	22^{9}	13th	8^{7}	7th to 8th
September	12^{19}	24th	23^{27}	11th	11^{5}	24th	25^{9}	26th	12^{1}	26th to 27th
October	13^{61}	18th	22^{71}	8th	12^{2}	18th	28^{0}	14th	11^{3}	28th to 29th
November	15^{59}	22d	31^{77}	26th	14^{1}	4th	35^{1}	26th	19^{1}	26th to 27th
December	15^{41}	27th	30^{70}	2d	13^{0}	27th	33^{7}	2d	16^{1}	2d to 3d
January	13^{54}	4th	34^{26}	25th	13^{0}	29th	34^{9}	25th	15^{1}	24th to 25th
February	12^{79}	25th	29^{92}	6th	12^{2}	25th	33^{4}	6th	17^{3}	6th to 7th
March	11^{93}	27th	27^{30}	2d	10^{2}	27th	28^{8}	20th	16^{4}	30th to 31st
April	9^{03}	30th	21^{89}	2d	7^{3}	30th	24^{0}	2d	12^{2}	1st to 2d

General average (by the month) for the year, 17^{45}%.
Lowest average periods, April '96, 14^{15}, and May, '95, 14^{86}%.
Highest average periods, November, '95, 22^{02}, and December, '95, 19^{28}%.
Lowest observation, April 30th, '96, 7^{3}%.
Highest observation, November 26th, '95, 35^{1}%.

The Value of Hartshorne's Work.

As I see it the true value of Mr. Hartshorne's work lies in the fact that his tables give a reliable starting point or basis to work from in textile manufacturing.

I cannot too strongly emphasize the remark he makes to the effect that a mill which weaves its own spinning and sells its product by the yard, the subject may seem of little or no importance from a commercial point of view, but even here the knowledge of what constitutes the best working conditions and what degree of atmospheric humidity for a given temperature will give the best results, may be of great importance.

Appreciating then that it is not conditions of uniform humidity either relative or actual, that make work run well in manufacturing, but the percentage of moisture in the fibres themselves, or their "regain," comes recognition of the invaluable character of Mr. Hartshorne's careful and painstaking

contribution to the art of manufacturing textile fibres. One is able to rationalize for the first time schedules of atmospheric conditions best adapted to a series of successive processes in the course of manufacture, with a reasonable degree of assurance that when once the best schedule for certain work under given conditions has been found, that it can be adhered to but with slight changes to fit different lots of cotton or other fibres, such changes consisting only of raising or lowering the scale a point or two to compensate for the greater or lesser amount of hygroscopicity in different lots of materials.

The extreme nicety of the proposition lies in the fact that standards of regain take into account not only relative humidity but temperature changes, so that maintaining definite percentages of regain in the different operations in manufacturing enables one to neglect or ignore temperature changes.*

Laws of Regain.

Just here it is well to boil down into a few brief paragraphs the laws that govern "regain," and the practical application of it becomes evident.

Throughout the ranges of temperature (60°—100° F.) and relative humidity (40%—80%) ordinarily dealt with in a textile factory,—

(1) For a given relative humidity, the regain is less at high temperatures than at low ones.

(2) So, to maintain a given percentage of regain, it is necessary to maintain an ascending scale of relative humidities if the temperature is rising, and a descending scale if it is falling.

(3) Further, while the rate of ascent or descent is variable throughout the whole range, that within the limits under consideration it is fairly constant.

(4) For a given difference of regain, an increasing difference of relative humidity is required as the temperature rises.

(5) But while the actual difference is increasing, the rate of increase is fairly constant.

(6) While the isothermals, or temperature curves, corresponding to regain and atmospheric moisture diverge greatly as the temperature rises, the curves of relative humidity are approximately parallel.

(7) And finally, from all of which, it is evident that a series of parallel and variable scales of relative humidity can be prepared that will approximate constant percentages of regain, regardless of changes in temperature.

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*It is needless to point out, however, that the closer temperatures are maintained, as well as the humidities that correspond thereto, the better will the work run, and the greater the comfort of the work room.

Hartshorne's Table of Worsted Regain.

Relative Humidity	Temperature of Air in Degrees Fahrenheit													
	35	40	45	50	55	60	65	70	75	80	85	90	95	100
15%	7.7	7.7	7.6	7.5	7.4	7.2	7.1	6.9	6.8	6.6	6.4	6.2	6.0	5.7
16	8.0	7.9	7.8	7.8	7.6	7.5	7.4	7.2	7.0	6.8	6.6	6.4	6.2	5.9
17	8.3	8.2	8.1	8.0	7.9	7.8	7.6	7.4	7.3	7.1	6.9	6.6	6.4	6.2
18	8.6	8.5	8.4	8.3	8.2	8.0	7.9	7.7	7.5	7.3	7.1	6.8	6.6	6.4
19	8.8	8.8	8.7	8.6	8.5	8.3	8.1	8.0	7.8	7.6	7.3	7.1	6.9	6.7
20	9.1	9.1	8.9	8.9	8.7	8.5	8.4	8.2	8.0	7.8	7.5	7.3	7.1	6.9
21	9.4	9.3	9.2	9.1	9.0	8.8	8.6	8.4	8.2	8.0	7.8	7.5	7.3	7.1
22	9.6	9.6	9.5	9.3	9.2	9.0	8.8	8.6	8.4	8.2	8.0	7.7	7.5	7.3
23	9.9	9.8	9.7	9.6	9.4	9.2	9.1	8.9	8.6	8.4	8.2	7.9	7.7	7.5
24	10.1	10.0	9.9	9.8	9.7	9.5	9.3	9.1	8.9	8.7	8.4	8.2	7.9	7.7
25	10.4	10.3	10.2	10.0	9.9	9.7	9.5	9.3	9.1	8.9	8.7	8.4	8.1	7.8
26	10.6	10.5	10.4	10.2	10.1	9.9	9.7	9.5	9.3	9.0	8.8	8.5	8.3	8.0
27	10.8	10.7	10.6	10.4	10.3	10.1	9.9	9.7	9.4	9.2	9.0	8.7	8.4	8.2
28	11.0	10.9	10.8	10.6	10.5	10.3	10.1	9.9	9.6	9.4	9.2	8.9	8.6	8.3
29	11.2	11.1	11.0	10.8	10.6	10.5	10.3	10.0	9.8	9.6	9.3	9.0	8.8	8.5
30	11.4	11.3	11.2	11.0	10.8	10.7	10.5	10.2	10.0	9.8	9.5	9.2	8.9	8.7
31	11.6	11.5	11.4	11.2	11.0	10.8	10.6	10.4	10.2	9.9	9.7	9.4	9.1	8.8
32	11.8	11.7	11.5	11.4	11.2	11.0	10.8	10.6	10.3	10.1	9.8	9.6	9.3	9.0
33	12.0	11.9	11.7	11.5	11.4	11.2	11.0	10.8	10.5	10.3	10.0	9.8	9.4	9.2
34	12.2	12.0	11.9	11.7	11.5	11.4	11.2	10.9	10.7	10.4	10.2	10.0	9.6	9.4
35	12.4	12.2	12.1	11.9	11.7	11.5	11.3	11.1	10.9	10.6	10.3	10.2	9.8	9.5
36	12.6	12.4	12 3	12.1	11.9	11.7	11.5	11.3	11.0	10.8	10.5	10.3	10.0	9.7

Note.—The results are in percentages, of course.

Hartshorne's Table of Worsted Regain, Continued.

Relative Humidity	Temperature of Air in Degrees Fahrenheit													
	35	40	45	50	55	60	65	70	75	80	85	90	95	100
37%	12.7	12.6	12.5	12.3	12.1	11.9	11.7	11.5	11.2	11.0	10.7	10.5	10.1	9.9
38	12.9	12.8	12.6	12.4	12.3	12.1	11.9	11.6	11.4	11.1	10.9	10.6	10.3	10.1
39	13.1	13.0	12.8	12.6	12.4	12.2	12.0	11.8	11.5	11.3	11.0	10.8	10.5	10.2
40	13.3	13.2	13.0	12.8	12.6	12.4	12.2	12.0	11.7	11.5	11.2	10.9	10.7	10.4
41	13.5	13.4	13.2	13.0	12.8	12.6	12.4	12.2	11.9	11.6	11.4	11.1	10.8	10.6
42	13.7	13.5	13.4	13.2	13.0	12.8	12.6	12.3	12.1	11.8	11.5	11.3	11.0	10.7
43	13.9	13.7	13.6	13.4	13.2	13.0	12.7	12.5	12.2	12.0	11.7	11.4	11.2	10.9
44	14.1	13.9	13.8	13.6	13.4	13.2	12.9	12.7	12.4	12.2	11.9	11.6	11.3	11.1
45	14.3	14.1	14.0	13.8	13.6	13.3	13.1	12.9	12.6	12.3	12.1	11.8	11.5	11.3
46	14.5	14.3	14.1	13.9	13.7	13.5	13.3	13.0	12.8	12.5	12.2	11.9	11.7	11.4
47	14.7	14.5	14.3	14.1	13.9	13.7	13.5	13.2	12.9	12.7	12.4	12.1	11.8	11.6
48	14.8	14.7	14.5	14.3	14.1	13.9	13.6	13.4	13.1	12.8	12.6	12.3	12.0	11.8
49	15.0	14.9	14.7	14.5	14.3	14.1	13.8	13.6	13.3	13.0	12.7	12.4	12.2	11.9
50	15.2	15.1	14.9	14.7	14.5	14.3	14.0	13.8	13.5	13.2	12.9	12.6	12.3	12.1
51	15.4	15.3	15.1	14.9	14.7	14.4	14.2	13.9	13.6	13.3	13.1	12.8	12.5	12.3
52	15.6	15.5	15.3	15.1	14.9	14.6	14.4	14.1	13.8	13.5	13.3	13.0	12.7	12.4
53	15.8	15.7	15.5	15.3	15.1	14.8	14.6	14.3	14.0	13.7	13.4	13.1	12.9	12.6
54	16.0	15.9	15.7	15.5	15.3	15.0	14.7	14.5	14.2	13.9	13.6	13.3	13.0	12.8
55	16.3	16.1	15.9	15.7	15.5	15.2	14.9	14.7	14.3	14.1	13.8	13.5	13.2	13.0
56	16.5	16.3	16.1	15.9	15.6	15.4	15.1	14.8	14.5	14.2	14.0	13.7	13.4	13.1
57	16.7	16.5	16.3	16.1	15.8	15.6	15.3	15.0	14.7	14.4	14.2	13.9	13.6	13.3
58	16.9	16.7	16.5	16.3	16.0	15.7	15.5	15.2	14.9	14.6	14.3	14.0	13.7	13.5

Hartshorne's Table of Worsted Regain, Continued.

Relative Humidity	Temperature of Air in Degrees Fahrenheit													
	35	40	45	50	55	60	65	70	75	80	85	90	95	100
59%	17.1	16.9	16.7	16.5	16.2	15.9	15.7	15.4	15.0	14.8	14.5	14.2	13.9	13.6
60	17.3	17.1	16.9	16.7	16.4	16.1	15.9	15.6	15.2	14.9	14.7	14.4	14.1	13.8
61	17.5	17.3	17.1	16.9	16.6	16.3	16.0	15.7	15.4	15.1	14.9	14.6	14.3	14.0
62	17.7	17.5	17.3	17.1	16.8	16.5	16.2	15.9	15.6	15.3	15.1	14.8	14.5	14.2
63	17.9	17.7	17.5	17.3	17.0	16.7	16.4	16.1	15.8	15.5	15.2	15.0	14.7	14.3
64	18.1	17.9	17.7	17.5	17.2	16.9	16.6	16.3	16.0	15.7	15.4	15.1	14.8	14.5
65	18.3	18.2	17.9	17.7	17.4	17.1	16.8	16.5	16.1	15.9	15.6	15.3	15.0	14.7
66	18.6	18.4	18.1	17.9	17.6	17.3	16.9	16.7	16.3	16.1	15.8	15.5	15.2	14.9
67	18.8	18.6	18.3	18.1	17.8	17.4	17.1	16.8	16.5	16.2	16.0	15.7	15.4	15.1
68	19.0	18.8	18.5	18.3	18.0	17.6	17.3	17.0	16.7	16.4	16.1	15.9	15.6	15.2
69	19.2	19.0	18.7	18.5	18.2	17.8	17.5	17.2	16.9	16.6	16.3	16.1	15.8	15.4
70	19.4	19.2	18.9	18.7	18.3	18.0	17.7	17.4	17.1	16.8	16.5	16.2	15.9	15.6
71	19.6	19.4	19.2	18.9	18.6	18.2	17.9	17.6	17.3	17.0	16.7	16.4	16.1	15.8
72	19.9	19.7	19.4	19.1	18.8	18.4	18.1	17.8	17.5	17.2	16.9	16.6	16.3	16.0
73	20.1	19.9	19.6	19.3	19.0	18.7	18.3	18.0	17.7	17.4	17.1	16.8	16.5	16.2
74	20.4	20.1	19.9	19.6	19.2	18.9	18.5	18.2	17.9	17.6	17.3	17.0	16.7	16.5
75	20.6	20.4	20.1	19.8	19.4	19.1	18.7	18.4	18.1	17.8	17.5	17.2	16.9	16.7
76	20.8	20.6	20.4	20.0	19.7	19.3	18.9	18.6	18.3	17.9	17.6	17.4	17.1	16.9
77	21.1	20.8	20.6	20.2	19.9	19.5	19.2	18.8	18.5	18.1	17.8	17.6	17.3	17.1
78	21.3	21.1	20.9	20.5	20.1	19.7	19.4	19.0	18.7	18.3	18.0	17.8	17.5	17.3
79	21.6	21.3	21.1	20.7	20.3	19.9	19.6	19.2	18.9	18.5	18.2	18.0	17.7	17.5

Hartshorne's Table of Worsted Regain, Concluded.

Relative Humidity	Temperature of Air in Degrees Fahrenheit													
	35	40	45	50	55	60	65	70	75	80	85	90	95	100
80%	21.8	21.5	21.3	20.9	20.6	20.2	19.8	19.4	19.1	18.7	18.4	18.2	17.9	17.7
81	22.1	21.8	21.6	21.2	20.8	20.4	20.0	19.6	19.3	18.9	18.6	18.4	18.2	18.0
82	22.3	22.1	21.8	21.4	21.0	20.6	20.2	19.8	19.5	19.1	18.9	18.7	18.5	18.3
83	22.6	22.3	22.1	21.7	21.3	20.9	20.4	20.0	19.7	19.4	19.1	18.9	18.8	18.6
84	22.9	22.6	22.4	22.0	21.5	21.1	20.7	20.2	19.9	19.6	19.3	19.2	19.1	18.9
85	23.2	22.9	22.6	22.2	21.8	21.3	20.9	20.4	20.2	19.8	19.6	19.4	19.4	19.2
86	23.4	23.2	22.9	22.5	22.0	21.6	21.1	20.7	20.4	20.1	19.8	19.7	19.6	19.5
87	23.7	23.4	23.1	22.7	22.3	21.9	21.4	21.0	20.7	20.3	20.1	20.0	19.9	19.8
88	24.0	23.7	23.4	23.0	22.6	22.1	21.7	21.3	20.9	20.6	20.4	20.3	20.2	20.2
89	24.2	24.0	23.6	23.2	22.8	22.4	21.9	21.5	21.2	20.8	20.6	20.6	20.5	20.5
90	24.5	24.2	23.9	23.5	23.1	22.7	22.2	21.8	21.4	21.1	20.9	20.9	20.8	20.8
91	24.8	24.6	24.2	23.8	23.4	23.0	22.5	22.1	21.8	21.4	21.3	21.2	21.2	21.1
92	25.2	24.9	24.6	24.2	23.7	23.3	22.8	22.4	22.1	21.7	21.6	21.5	21.6	21.5
93	25.5	25.3	24.9	24.5	24.1	23.6	23.1	22.7	22.4	22.1	21.9	21.9	22.0	21.9
94	25.9	25.6	25.3	24.9	24.4	23.9	23.4	23.0	22.8	22.4	22.3	22.2	22.3	22.3
95	26.2	26.0	25.6	25.2	24.7	24.2	23.7	23.3	23.1	22.7	22.6	22.6	22.7	22.7
96	26.6	26.3	26.0	25.6	25.1	24.6	24.1	23.7	23.5	23.1	23.0	23.0	23.1	23.1
97	27.0	26.7	26.4	26.0	25.5	25.0	24.5	24.1	23.9	23.5	23.4	23.4	23.5	23.4
98	27.4	27.1	26.7	26.3	25.9	25.4	24.9	24.5	24.2	24.0	23.8	23.8	23.9	23.8
99	27.8	27.4	27.1	26.7	26.3	25.8	25.4	24.9	24.6	24.4	24.3	24.2	24.3	24.2
100	28.2	27.8	27.5	27.1	26.7	26.2	25.8	25.4	25.0	24.8	24.7	24.7	24.6	24.6

Hartshorne's Table of Cotton Regain.

Relative Humidity	Degrees Fahrenheit 40	45	50	55	60	65	70	75	80	85	90	95	100
15%	2.93	2.91	2.90	2.87	2.84	2.81	2.79	2.73	2.68	2.63	2.57	2.50	2.40
16	3.07	3.05	3.04	3.01	2.98	2.95	2.92	2.86	2.81	2.76	2.70	2.62	2.52
17	3.21	3.19	3.18	3.15	3.12	3.09	3.05	3.00	2.95	2.90	2.83	2.74	2.64
18	3.35	3.33	3.32	3.29	3.26	3.23	3.19	3.13	3.08	3.03	2.96	2.86	2.76
19	3.49	3.47	3.46	3.43	3.40	3.37	3.32	3.27	3.22	3.17	3.09	2.98	2.88
20	3.63	3.61	3.60	3.58	3.54	3.50	3.45	3.40	3.35	3.30	3.21	3.10	3.00
21	3.76	3.74	3.73	3.[illegible]0	3.66	3.62	3.57	3.52	3.46	3.41	3.32	3.21	3.10
22	3.90	3.87	3.85	3.83	3.79	3.75	3.69	3.64	3.58	3.52	3.42	3.31	3.20
23	4.03	4.00	3.98	3.95	3.91	3.87	3.81	3.76	3.69	3.63	3.53	3.43	3.30
24	4.17	4.13	4.11	4.08	4.04	4.00	3.93	3.88	3.81	3.74	3.64	3.53	3.40
25	4.30	4.27	4.24	4.20	4.16	4.12	4.06	4.00	3.92	3.85	3.75	3.64	3.50
26	4.41	4.39	4.36	4.32	4.28	4.24	4.18	4.12	4.04	3.96	3.86	3.75	3.61
27	4.53	4.51	4.48	4.44	4.40	4.35	4.30	4.24	4.15	4.07	3.97	3.86	3.72
28	4.65	4.63	4.60	4.56	4.52	4.47	4.42	4.36	4.27	4.18	4.08	3.97	3.83
29	4.77	4.75	4.72	4.68	4.64	4.58	4.54	4.48	4.38	4.29	4.19	4.08	3.94
30	4.89	4.87	4.84	4.80	4.75	4.70	4.65	4.60	4.50	4.40	4.30	4.20	4.06
31	5.00	4.98	4.95	4.90	4.85	4.80	4.75	4.70	4.60	4.50	4.40	4.29	4.16
32	5.10	5.08	5.05	5.01	4.96	4.90	4.85	4.80	4.69	4.59	4.49	4.39	4.26
33	5.21	5.19	5.16	5.11	5.06	5.01	4.95	4.90	4.79	4.69	4.59	4.48	4.36
34	5.31	5.29	5.26	5.21	5.17	5.11	5.05	4.99	4.89	4.79	4.68	4.58	4.46
35	5.42	5.40	5.37	5.32	5.27	5.21	5.15	5.09	4.99	4.89	4.78	4.67	4.56
36	5.53	5.51	5.48	5.42	5.37	5.31	5.25	5.19	5.08	4.98	4.87	4.76	4.66

Hartshorne's Table of Cotton Regain, Continued.

Relative Humidity	Degrees Fahrenheit												
	40	45	50	55	60	65	70	75	80	85	90	95	100
37%	5.63	5.61	5.58	5.52	5.48	5.41	5.35	5.29	5.18	5.08	4.97	4.86	4.75
38	5.74	5.72	5.69	5.62	5.58	5.52	5.45	5.38	5.28	5.18	5.06	4.95	4.85
39	5.84	5.82	5.79	5.73	5.69	5.62	5.55	5.48	5.37	5.27	5.15	5.05	4.95
40	5.95	5.93	5.90	5.83	5.79	5.72	5.65	5.58	5.47	5.37	5.25	5.14	5.05
41	6.05	6.03	6.00	5.93	5.89	5.82	5.75	5.68	5.57	5.47	5.34	5.23	5.13
42	6.15	6.13	6.10	6.03	5.99	5.92	5.85	5.78	5.67	5.57	5.44	5.32	5.21
43	6.25	6.23	6.20	6.13	6.09	6.02	5.94	5.87	5.77	5.67	5.53	5.41	5.29
44	6.35	6.33	6.30	6.23	6.19	6.12	6.04	5.97	5.86	5.76	5.62	5.50	5.37
45	6.45	6.43	6.40	6.33	6.28	6.22	6.14	6.07	5.96	5.86	5.72	5.59	5.46
46	6.55	6.53	6.50	6.43	6.38	6.31	6.24	6.16	6.06	5.96	5.81	5.68	5.54
47	6.65	6.62	6.59	6.53	6.48	6.41	6.33	6.26	6.15	6.05	5.90	5.77	5.62
48	6.75	6.72	6.69	6.63	6.58	6.51	6.43	6.35	6.25	6.15	5.99	5.86	5.70
49	6.85	6.82	6.79	6.73	6.68	6.61	6.53	6.45	6.35	6.25	6.09	5.95	5.78
50	6.95	6.92	6.89	6.83	6.78	6.71	6.63	6.55	6.45	6.35	6.18	6.04	5.86
51	7.07	7.03	7.00	6.94	6.89	6.82	6.74	6.65	6.55	6.44	6.27	6.13	5.95
52	7.18	7.15	7.11	7.05	7.00	6.93	6.84	6.75	6.65	6.54	6.37	6.23	6.05
53	7.30	7.26	7.22	7.16	7.11	7.04	6.95	6.85	6.75	6.63	6.46	6.32	6.14
54	7.41	7.38	7.33	7.27	7.22	7.14	7.05	6.96	6.85	6.73	6.56	6.42	6.24
55	7.53	7.49	7.44	7.38	7.33	7.25	7.16	7.06	6.95	6.82	6.65	6.51	6.33
56	7.65	7.60	7.56	7.49	7.43	7.36	7.27	7.16	7.04	6.92	6.75	6.61	6.42
57	7.76	7.72	7.67	7.60	7.54	7.46	7.37	7.27	7.14	7.01	6.84	6.70	6.52

Hartshorne's Table of Cotton Regain, Continued.

Relative Humidity	Degrees Fahrenheit 40	45	50	55	60	65	70	75	80	85	90	95	100
58%	7.88	7.83	7.78	7.71	7.65	7.57	7.48	7.37	7.24	7.11	6.94	6.80	6.61
59	7.99	7.95	7.89	7.82	7.76	7.68	7.58	7.47	7.34	7.20	7.03	6.89	6.71
60	8.11	8.06	8.00	7.93	7.87	7.79	7.69	7.57	7.44	7.30	7.13	6.98	6.80
61	8.22	8.17	8.14	8.04	7.98	7.90	7.80	7.68	7.55	7.41	7.25	7.10	6.92
62	8.34	8.29	8.23	8.16	8.10	8.01	7.91	7.79	7.67	7.53	7.37	7.22	7.05
63	8.45	8.40	8.34	8.27	8.21	8.12	8.02	7.91	7.78	7.64	7.49	7.35	7.17
64	8.57	8.52	8.46	8.39	8.32	8.23	8.13	8.02	7.90	7.76	7.61	7.47	7.30
65	8.68	8.63	8.57	8.50	8.43	8.34	8.24	8.13	8.01	7.87	7.72	7.59	7.42
66	8.79	8.74	8.68	8.62	8.55	8.45	8.35	8.24	8.12	7.98	7.84	7.71	7.55
67	8.91	8.86	8.80	8.73	8.66	8.56	8.46	8.35	8.24	8.10	7.96	7.83	7.67
68	9.02	8.97	8.91	8.85	8.77	8.67	8.57	8.47	8.35	8.21	8.08	7.96	7.80
69	9.14	9.09	9.03	8.96	8.89	8.78	8.68	8.58	8.47	8.33	8.20	8.08	7.92
70	9.25	9.20	9.14	9.08	9.00	8.89	8.79	8.69	8.58	8.44	8.32	8.20	8.05
71	9.40	9.34	9.28	9.22	9.14	9.03	8.93	8.83	8.72	8.58	8.46	8.34	8.20
72	9.54	9.49	9.43	9.36	9.28	9.18	9.08	8.97	8.85	8.72	8.60	8.49	8.36
73	9.69	9.63	9.57	9.51	9.43	9.32	9.22	9.11	8.99	8.86	8.73	8.63	8.51
74	9.83	9.77	9.72	9.65	9.57	9.47	9.37	9.25	9.13	9.00	8.87	8.78	8.67
75	9.98	9.91	9.86	9.79	9.71	9.61	9.51	9.40	9.26	9.13	9.01	8.92	8.82
76	10.12	10.06	10.00	9.93	9.85	9.75	9.65	9.54	9.40	9.27	9.15	9.06	8.98
77	10.27	10.20	10.15	10.07	9.99	9.90	9.80	9.68	9.54	9.41	9.29	9.21	9.13
78	10.41	10.34	10.29	10.22	10.14	10.04	9.94	9.82	9.68	9.55	9.42	9.35	9.29
79	10.56	10.49	10.44	10.36	10.28	10.19	10.07	9.96	9.81	9.69	9.56	9.50	9.44

Hartshorne's Table of Cotton Regain, Concluded.

Relative Humidity	Degrees Fahrenheit 40	45	50	55	60	65	70	75	80	85	90	95	100
80%	10.70	10.63	10.58	10.50	10.42	10.33	10.23	10.10	9.95	9.83	9.70	9.64	9.60
81	10.87	10.80	10.75	10.67	10.59	10.49	10.39	10.26	10.11	9.99	9.87	9.83	9.82
82	11.04	10.97	10.92	10.84	10.76	10.66	10.55	10.42	10.27	10.16	10.05	10.01	10.05
83	11.21	11.14	11.09	11.01	10.92	10.82	10.72	10.58	10.43	10.32	10.22	10.20	10.27
84	11.38	11.31	11.26	11.18	11.09	10.99	10.88	10.74	10.59	10.48	10.39	10.38	10.50
85	11.55	11.48	11.43	11.35	11.26	11.15	11.04	10.90	10.75	10.64	10.56	10.57	10.72
86	11.71	11.65	11.60	11.52	11.43	11.32	11.20	11.06	10.92	10.81	10.74	10.76	10.95
87	11.88	11.82	11.77	11.69	11.60	11.48	11.36	11.22	11.08	10.97	10.91	10.94	11.17
88	12.05	11.99	11.94	11.86	11.76	11.65	11.53	11.38	11.24	11.13	11.08	11.13	11.40
99	12.22	12.16	12.11	12.03	11.93	11.81	11.69	11.54	11.40	11.30	11.26	11.31	11.62
90	12.39	12.33	12.28	12.20	12.10	11.98	11.85	11.70	11.56	11.46	11.43	11.50	11.85
91	12.57	12.51	12.46	12.39	12.29	12.17	12.04	11.90	11.77	11.68	11.66	11.75	12.11
92	12.75	12.70	12.65	12.58	12.48	12.36	12.24	12.10	11.98	11.90	11.88	12.00	12.38
93	12.94	12.88	12.83	12.76	12.67	12.56	12.43	12.30	12.19	12.12	12.11	12.25	12.64
94	13.12	13.07	13.02	12.95	12.86	12.75	12.63	12.50	12.40	12.34	12.34	12.50	12.91
95	13.30	13.25	13.20	13.14	13.05	12.94	12.82	12.70	12.61	12.56	12.56	12.75	13.17
96	13.48	13.44	13.38	13.33	13.24	13.13	13.02	12.90	12.81	12.77	12.79	13.00	13.44
97	13.66	13.62	13.57	13.52	13.43	13.33	13.21	13.10	13.02	12.99	13.02	13.25	13.70
98	13.85	13.81	13.75	13.70	13.62	13.52	13.41	13.30	13.23	13.21	13.25	13.50	13.97
99	14.03	13.99	13.94	13.89	13.81	13.71	13.60	13.50	13.44	13.43	13.47	13.75	14.23
100	14.21	14.18	14.12	14.08	14.00	13.90	13.80	13.70	13.65	13.65	13.70	14.00	14.50

Extract from Hygrometric Properties of Textile Materials.

(A report made to the Societe d'Encouragement pour L'Industrie Nationale, Paris, France, 1893, reprinted from Textile World Record.)

"Textile materials possess very marked hygroscopic properties.

"The quantity of water that a hygroscopic material in equilibrium with the surrounding air contains is a function of two variables: The relative humidity of the air and the temperature. * * * * * * *

"When, therefore, an equilibrium of humidity is established between a hygroscopic material and the surrounding air, there is at each temperature a relation between the humidity of the material and the relative degree of humidity of the air, so that a given value for the latter corresponds to a certain value for the former. It is this relation that I have studied. * * * * * * * * *

"Following are the results based on 100 parts of the absolutely dry material:

Cottons.

Relative Humidity of Air at 24° C. (75.2° F.)	Water per 100 parts Dry Material (Regain)		
	American Cotton	Egyptian Cotton	Indian Cotton
51%	6.25	6.75	6.90
71-½	8.40	8.95	10.15
83	10.95	10.30	11.85

Wools.

Relative Humidity of Air at 24° C. (75.2° F.)	Water per 100 parts Dry Material (Regain)	
	Buenos Ayres Cross Bred, Combed	Port Phillip Merino, Combed
15%	5.55	.....
25.8	.....	8.30
37.8	11.20	.....
61.8	.....	14.90
65.6	15.25	.....
81.9	19.10	.....
86.30	.....	21.90

Silks.

Relative Humidity of Air at 24° C. (75.2° F.)	Water per 100 parts Dry Material (Regain)	
	Raw Cervennes	Boiled off Cervennes
32.6%	.....	6.55
35.1	7.50	.....
56.3	9.70	.....
71.3	.....	11.60
78.6	14.20	.....
82.2	.....	14.65
86.1	16.50	.....

Conclusions.—All the curves have the same general deviation. (See next page.)

* * * * * * * * *

"As regards the cottons, they give evidence of notable differences between the three samples examined. Do these differences result from the source of the samples, or are they due to a variation in the properties, which are independent of the place of origin? To decide this point it will be necessary to experiment further on a number of samples from the three sources, but such as they are, the results obtained proved that all the cottons do not act the same in the presence of moist air. That is to say, they absorb at the same temperature sensibly different amounts of moisture when in presence of atmospheres having the same relative humidity.

"The boiled off raw silk absorbed slightly less moisture than the raw silk of the same origin; this is explained by the removal of the gummy matter, which is very hygroscopic. There is very little difference between the two silks taken in the same condition.

"The two samples of wool with which I experimented gave practically the same results so that these results can be given by one curve.

* * * * * * * * *

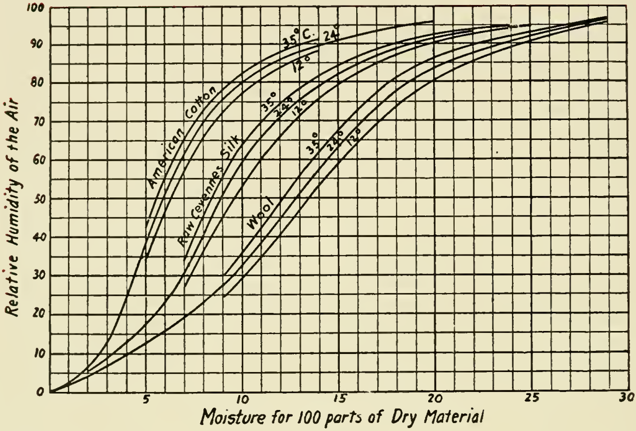
"Representing the results by curves: (See next page.)

"All these curves cannot be traced on the same chart without introducing confusion. Accordingly, the first chart shows the curves for one temperature 24° (it is a good plan to represent them alongside each other in order to facilitate comparison); the second chart gives the curves for a sample of each of the three materials, cotton, silk and wool, so as to show the influence of the temperature on their hygroscopicity."

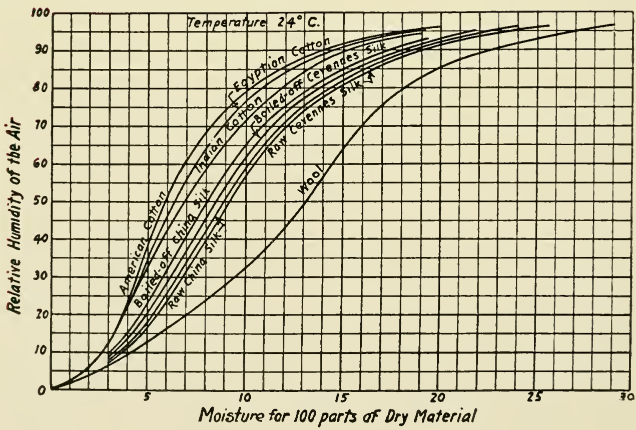
"The proportion of humidity based on 100 parts of absolutely dry material have been taken for the abscissae, and the degrees of relative humidity of the air have been taken for the ordinates."

In order to economize space, M. Schloessing's report has been greatly abridged and condensed,—even the tables have been cut down, so that results have been given only at 24° C. (75.2° F.) which is sufficient for comparative data, as the curves show the effect of different temperatures.

SCHLOESSING'S CHARTS.



(Diagram I.)



(Diagram II.)

Climate and Regain.

Climate.

The principal elements affecting climate are temperature and precipitation, and of these temperature is the more important. The principal considerations affecting climate are distances from the sea coast and the equator, elevations above sea-level and prevailing winds. Inland climates have generally greater changes in temperature both from day to night and from summer to winter than coast climates in the same latitudes; the same is true of Northern climates as compared to Southern climates. Dry climates are generally subject to greater changes than moist ones.

In the accompanying tables, the temperatures are mean temperatures. Daily mean temperature is the average of the highest and lowest for the day at the place and taken generally by maximum and minimum thermometers, though sometimes and more accurately by averaging the hourly records of recording thermometers. The monthly mean is, of course, an average of the daily mean temperatures.

The amounts of evaporation and precipitation are the chief local conditions affecting temperature. The amount of evaporation during the year varies greatly in different localities; in New England it averages 39 inches and in the Middle Atlantic States it approximates 43 inches. The amounts of precipitation or rainfall do not so readily classify; but, for example, the annual figure for North Carolina is 53 inches, August being the wettest month with 6.09 and November the driest with 3.40.

Effect of Climate on the Physical Characteristics of Cotton.

Short Staple or Upland American Cotton is grown in a climate whose mean temperature and relative humidity during the periods of growth and maturity are respectively 73° F. and 66% relative humidity.

Long Staple American is grown under conditions of 80° F. and 75% relative humidity.

It is an axiom that fine yarns require higher humidities for ring spinning than those for medium and coarse yarns. That a part of it is because of the greater strength required for the fine yarns to stand the rough handling seems proved, because mule spun yarns require less moisture, probably because of the greater tenderness with which they are handled in spinning; but it is also likely that a part of it is due to the fact that

Table I *Showing Outside Conditions.*

(January to June.)

Localities	January				February				March				April				May				June			
	Temperatures		Relative Humidity	Cotton Regain	Temperatures		Relative Humidity	Cotton Regain	Temperatures		Relative Humidity	Cotton Regain	Temperatures		Relative Humidity	Cotton Regain	Temperatures		Relative Humidity	Cotton Regain	Temperatures		Relative Humidity	Cotton Regain
	Dry Bulb	Wet Bulb			Dry Bulb	Wet Bulb			Dry Bulb	Wet Bulb			Dry Bulb	Wet Bulb			Dry Bulb	Wet Bulb			Dry Bulb	Wet Bulb		
	°F	°F	%	%	°F	°F	%	%	°F	°F	%	%	°F	°F	%	%	°F	°F	%	%	°F	°F	%	%
Bombay, India	73.0	67.0	70.0	8.7	75.0	69.0	69.0	8.6	79.0	73.0	72.0	8.9	83.0	79.0	80.0	9.9	85.0	81.0	80.0	9.8	83.0	79.5	82.0	10.2
Mobile, Ala...........	51.0	48.5	82.9	11.1	54.0	51.5	82.6	10.9	59.5	56.5	81.0	10.6	67.0	63.0	78.2	10.0	74.0	70.0	79.4	10.0	80.0	76.0	79.4	9.9
Augusta, Ga...........	47.0	43.5	75.5	10.0	50.0	45.5	72.8	9.6	56.5	51.5	69.9	9.0	63.5	57.0	65.6	8.5	72.5	65.6	66.9	8.4	79.0	73.5	72.6	9.1
New Orleans, La......	54.0	51.0	78.9	10.3	57.5	54.5	80.1	10.5	62.5	58.5	76.8	9.9	69.0	64.5	74.9	9.5	75.0	70.0	73.1	9.1	80.5	76.0	77.2	9.6
Atlanta, Ga...........	42.5	39.0	76.4	10.1	46.0	42.0	73.2	9.6	52.0	47.0	69.7	9.1	61.0	54.5	64.5	8.4	69.5	62.5	64.1	8.2	76.0	70.0	70.7	8.7
Charlotte, N. C........	41.0	37.0	71.6	9.5	44.0	40.0	70.0	9.2	50.5	45.6	68.9	9.0	59.5	52.7	62.2	8.1	69.0	62.5	65.9	8.3	76.0	70.5	71.9	9.0
Philadelphia, Pa..	32.5	30.1	73.1	9.7	34.0	31.0	71.8	9.6	39.5	35.7	68.2	9.0	51.0	45.0	62.7	8.3	62.5	56.5	68.3	8.7	72.0	65.5	67.9	8.5
New Bedford, Mass....	28.0	27.1	82.0	11.2	29.0	28.2	86.0	11.8	35.0	33.4	84.0	11.5	44.0	40.8	75.0	9.9	55.0	51.0	76.0	9.9	64.0	60.0	78.0	10.1
Albany, N. Y..........	23.0	22.3	80.4	11.1	24.0	23.2	78.9	10.8	32.0	30.2	76.9	10.3	47.0	42.5	69.3	9.1	59.5	54.5	71.4	9.2	68.5	63.4	71.9	9.1
Boston, Mass,.........	27.0	25.7	72.1	9.7	28.0	26.5	71.2	9.6	34.5	31.2	68.2	9.1	45.5	40.5	65.9	8.7	57.0	52.0	70.6	9.1	67.0	61.5	71.6	9.1
Portland, Me...........	22.5	21.6	75.3	10.2	24.5	23.5	74.0	10.0	32.0	29.7	72.3	9.6	43.5	39.3	69.2	9.1	54.0	50.5	76.1	10.0	63.5	58.5	76.1	9.8
Bolton, England.......	37.0	36.5	99.0	14.1	40.0	38.5	88.0	12.0	39.0	37.0	83.0	11.2	44.0	40.0	79.0	10.5	49.0	45.0	73.0	9.6	58.0	53.5	73.0	9.5
Phoenix, Ariz..........	50.0	41.5	51.7	7.1	54.0	43.0	42.0	6.5	60.0	46.0	37.7	5.5	67.0	50.0	32.5	4.9	79.5	57.7	26.8	4.1	83.0	58.0	23.3	3.7

Table I Showing Outside Conditions.

(July to December.)

Localities	July				August				September				October				November				December			
	Temperatures		Relative Humidity	Cotton Regain	Temperatures		Relative Humidity	Cotton Regain	Temperatures		Relative Humidity	Cotton Regain	Temperatures		Relative Humidity	Cotton Regain	Temperatures		Relative Humidity	Cotton Regain	Temperatures		Relative Humidity	Cotton Regain
	Dry Bulb	Wet Bulb			Dry Bulb	Wet Bulb			Dry Bulb	Wet Bulb			Dry Bulb	Wet Bulb			Dry Bulb	Wet Bulb			Dry Bulb	Wet Bulb		
	°F	°F	%	%	°F	°F	%	%	°F	°F	%	%	°F	°F	%	%	°F	°F	%	%	°F	°F	%	%
Bombay, India........	81.0	78.0	86.0	10.9	80.0	77.5	87.0	11.1	80.0	77.0	86.0	10.9	89.3	85.0	80.0	9.7	79.0	71.0	64.0	7.9	76.0	70.0	70.0	8.7
Mobile, Ala............	82.0	78.5	82.1	10.2	81.0	78.0	84.0	10.6	77.5	74.0	81.0	10.2	68.0	64.0	78.3	10.1	59.0	56.0	81.6	10.7	52.5	50.0	83.6	11.1
Augusta, Ga...........	81.5	76.5	76.4	9.8	80.0	76.0	80.1	9.9	75.5	71.5	78.1	9.8	64 5	60.5	76.8	10.0	54.5	50.5	77.6	10.1	48.0	45.0	78.1	10.3
New Orleans, La......	82.5	77.5	77.7	9.6	81.5	77.0	78.9	9.8	78.5	74.0	77.1	9.6	70.5	65.5	74.5	9.4	61.5	58.0	78.8	10.2	55.5	51.5	79.4	10.4
Atlanta, Ga............	78.5	73.5	75.6	9.3	77.0	73.0	78.3	9.8	72.5	67.5	73.9	9.3	62.5	57.0	69.9	8.9	51.5	47.0	73.0	9.6	45.0	41.5	75.5	10.0
Charlotte, N. C........	78.5	73.5	75.1	9.6	77.0	72.5	77.6	9.6	71.5	67.0	75.6	9.6	60.5	55.5	71.0	9.1	50.5	46.0	70.7	9.2	43.5	39.5	72.3	9.5
Philadelphia, Pa.......	76.5	70.0	69.8	9.4	75.0	69.5	71.9	9.0	68.0	63.0	74.2	9.4	57.0	52.5	71.9	9.3	45.0	41.0	72.4	9.5	36.5	33.0	71.4	9.6
New Bedford, Mass....	70.0	67.0	82.0	11.2	68.0	66.0	88.0	11.6	62.0	59.5	85.0	11.2	52.0	49.0	81.0	10.7	42.0	39.5	80.0	10.7	32.0	31.0	87.0	12.0
Albany, N. Y..........	73.0	67.5	71.9	10.0	71.0	66.5	75.7	9.6	63.5	59.5	77.3	10.0	51.5	48.5	79.3	10.4	39.0	36.5	80.7	10.8	29.0	27.9	81.3	11.0
Boston, Mass..........	72.0	66.5	71.4	9.9	70.0	65.5	75.4	9.5	63.0	59.0	76.9	9.9	52.5	48.5	74.7	9.7	41.5	38.0	75.3	10.0	31.5	29.3	71.4	9.5
Portland, Me..........	69.0	64.5	76.4	10.6	67.0	63.5	80.3	10.3	60.0	57.0	81.0	10.6	49.5	46.5	78.9	10.4	38.5	35.5	76.7	10.2	28.0	26.7	75.4	10.3
Bolton, England.......	59.0	54.5	74.0	10.8	58.0	56.5	89.0	12.0	55.0	52.0	82.0	10.8	47.0	45.0	86.0	11.6	43.0	41.5	88.0	12.0	37.0	35.5	89.0	12.3
Phoenix, Ariz.........	89.5	70.5	36.3	5.4	87.5	72.5	43.3	5.6	81.5	65.0	39.3	5.4	70.0	56.0	41.1	5.8	60.0	48.0	43.6	6.1	53.0	41.5	41.3	6.0

Table II Showing Inside Conditions.

(January to June.)

Localities	January			February			March			April			May			June		
	Temperature	Relative Humidity	Cotton Regain	Temperature	Relative Humidity	Cotton Regain	Temperature	Relative Humidity	Cotton Regain	Temperature	Relative Humidity	Cotton Regain	Temperature	Relative Humidity	Cotton Regain	Temperature	Relative Humidity	Cotton Regain
	°F	%	%	°F	%	%	°F	%	%	°F	%	%	°F	%	%	°F	%	%
Bombay, India		65.7	8.2		69.0	8.6	79	72.0	8.9	83	80.0	9.9	85	80.0	9.8	83	82.0	10.2
Mobile, Ala		37.4	5.3		41.4	5.7		48.8	6.4		60.5	7.6		76.9	9.7	80	79.4	9.9
Augusta, Ga		29.6	4.5		31.7	4.8		38.2	5.4		45.3	6.1		61.8	7.8	79	72.6	9.1
New Orleans, La		39.5	5.5		45.2	6.1		43.1	5.9		61.7	7.8		73.1	9.1	80.5	77.2	9.6
Atlanta, Ga		25.4	4.0		27.7	4.3		32.5	4.9		40.9	5.7		53.8	6.9	76	70.7	8.7
Charlotte, N. C		22.6	3.7		24.6	3.9		30.6	4.7		37.5	5.3		54.4	7.0	76	71.9	9.0
Philadelphia, Pa		16.8	3.0		17.5	3.1		20.4	3.4		28.3	4.4		34.8	5.0		61.8	7.8
New Bedford, Mass		15.5	2.8		17.0	3.0		21.3	3.5		26.4	4.1		39.3	5.5		54.7	7.0
Albany, N. Y		12.2	2.3		12.5	2.4		17.3	3.1		27.1	4.3		43.1	5.9		58.4	7.4
Boston, Mass		13.0	2.5		13.5	2.5		16.9	3.0		24.4	3.9		39.1	5.5		55.4	7.1
Portland, Me		11.1	2.2		12.0	2.3		16.3	2.9		24.0	3.9		38.1	5.4		52.4	6.8
Bolton, England		26.9	4.2		26.8	4.2		24.4	3.9		27.8	4.3		30.7	4.7		41.9	5.8
Phoenix, Ariz		22.5	3.7		23.5	3.8		23.1	3.8		25.1	4.0	79.5	26.8	4.1	83	23.3	3.7

Table II Showing Inside Conditions.

(July to December.)

Localities	July Temperature	July Relative Humidity	July Cotton Regain	August Temperature	August Relative Humidity	August Cotton Regain	September Temperature	September Relative Humidity	September Cotton Regain	October Temperature	October Relative Humidity	October Cotton Regain	November Temperature	November Relative Humidity	November Cotton Regain	December Temperature	December Relative Humidity	December Cotton Regain
	°F	%	%	°F	%	%	°F	%	%	°F	%	%	°F	%	%	°F	%	%
Bombay, India	81	86.0	10.9	80	87.0	11.1	80	86.0	10.9	89	80.0	9.7	79	64.0	7.9	76	70.0	8.7
Mobile, Ala	82	82.1	10.2	81	84.0	10.6	77	81.0	10.2		62.6	7.9		48.4	6.4		39.8	5.6
Augusta, Ga	81.5	76.4	9.5	80	80.1	9.9	75	78.1	9.8		54.7	7.0		39.5	5.5		31.7	4.8
New Orleans, La	82.5	77.7	9.5	81.5	78.9	9.8	78	77.1	9.6		64.6	8.1		50.9	6.6		41.9	5.8
Atlanta, Ga	78.5	75.6	9.4	77	78.3	9.8		68.3	8.5		46.7	6.2		33.6	5.0		27.5	4.3
Charlotte, N. C	78.5	75.1	9.3	77	77.6	9.6		67.7	8.4		44.4	6.0		31.3	4.7		25.0	4.0
Philadelphia, Pa	76.5	69.8	8.7		71.9	9.0		59.3	7.5		39.9	5.6		26.4	4.1		19.1	3.3
New Bedford, Mass		69.9	8.7		70.3	8.7		55.8	7.1		37.8	5.4		26.2	4.1		19.7	3.4
Albany, N. Y		67.4	8.4		66.3	8.3		53.3	6.8		36.6	5.2		23.7	3.9		16.1	2.9
Boston, Mass		4.9	8.1		64.3	8.0		52.2	6.8		35.5	5.1		24.3	3.9		15.7	2.8
Portland, Me		63.0	7.9		62.1	7.8		49.7	6.5		33.8	5.0		22.1	3.6		14.3	2.6
Bolton, England		43.9	6.0		51.1	6.7		42.4	5.8		33.7	5.0		29.9	4.6		21.3	3.9
Phoenix, Ariz	89.5	36.3	4.9	87.5	43.3	5.6	81	39.3	5.4		35.1	5.1		26.7	4.2		20.0	3.4

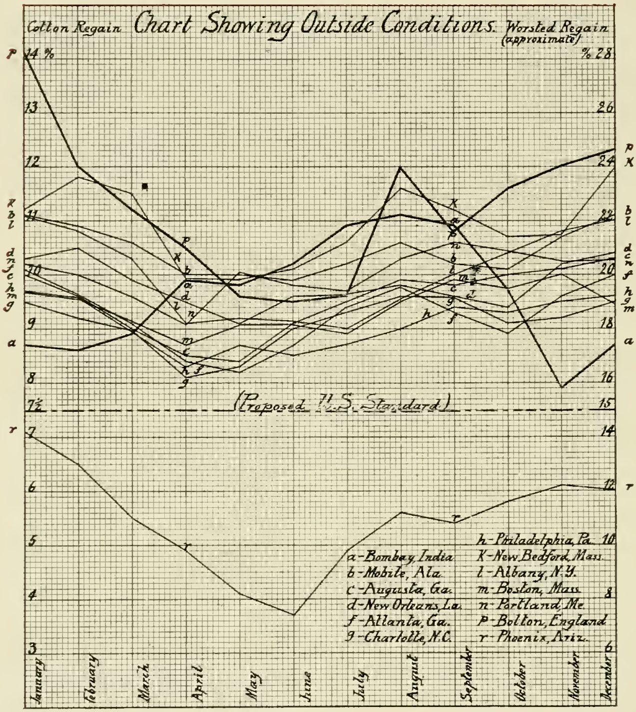


Chart I.

the grade of cotton from which they are made is higher, being long staple, and grown under higher conditions of humidity and temperature,—in its normal condition containing more moisture. The regains for the above conditions of growth, according to Hartshorne's tables, are 8.29% for Short Staple Upland and 10.10% for Long Staple Cottons. While neither of these conditions are likely to be duplicated in manufacturing for a number of reasons, they do serve to arrest attention to the fact that what will suit one is by no means an index for the other, and that climatic conditions during growth affect the problem as well as technical conditions in processes of manufacture.

So much has been said about the especial fitness of some localities for textile manufacturing that a few remarks on that point are distinctly in order.

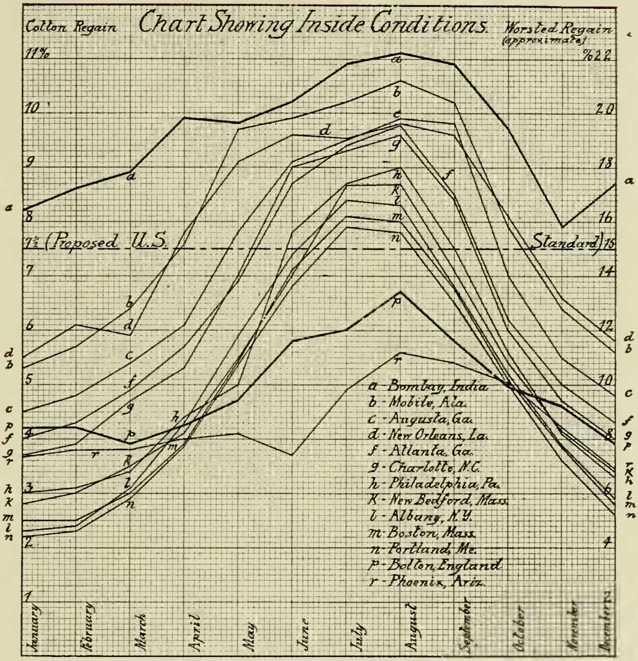


Chart II.

Localities in which the Atmosphere is Favorable to Manufacturing.

It had long been the hobby of Englishmen that there was not a climate in the world that rivaled the Bolton district in suitability for manufacturing; but of all places, the development of artificial moistening systems has been carried further there and their adoption more general. Certain districts in Northern France (Flanders) and in New England made the same claims, but they too have almost universally adopted artificially controlled atmospheres. Today any section where other conditions are favorable can possess the same atmosphere as the most favored, for all endeavor to maintain it artificially and to control it to their varied wishes. Good, clean fresh air to start with is all that is required.

Still, comparisons are both instructive and generally interesting and therefore the foregoing tables have been prepared comparing the climates of some of the best known

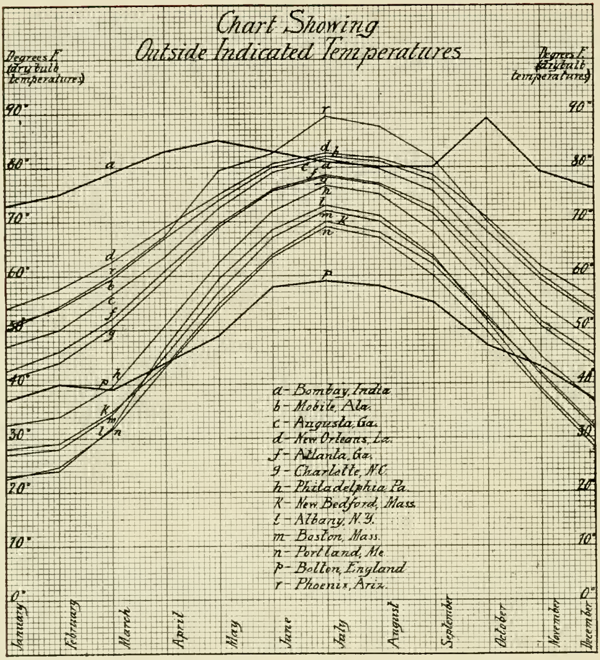


Chart III.

manufacturing centers in this country to that of the Bolton district. Bombay has been included for its climate is peculiarly different from that of the others; and Phoenix, Arizona, has been added, by way of contrast, as it has one of the dryest climates in the world.

It will be noticed that New Bedford and Bolton have about the same mean annual temperatures, 48° and 47° respectively, although there is a greater range of temperature in the former than in the latter,—an advantage in favor of Bolton.

Again, the relative humidity of the two places is practically the same, 80% and 84 1-6% respectively,—the difference in range is slightly in favor of Bolton.

But,—a careful inspection of the tables and the three accompanying charts plotted from them discloses some very remarkable and surprising results, as will be shown.

Effect of Climate on Regain.

I believe that plotting and charting climate as affecting manufacturing, by expressing it in terms of regain, is new, and the foregoing tables and charts therefore, require some explanation.

Table I. shows the atmospheric conditions, the year through, for the localities named; the temperature and relative humidity are given as usual; the wet bulb temperature is also added for it is now recognized as the real climatic temperature affecting health and comfort, and the Cotton Regain is added as the element pertinent to manufacturing adaptability. In other words, Table I., shows outside conditions, as they may be termed; and Charts II., and III., are plotted therefrom.

Table II., is calculated from Table I., by assuming a constant minimum dry bulb temperature of 75°, to which temperature or above, it is assumed that a mill would be heated in fall, winter and spring; in other words, Table II., represents inside conditions.

By the terms "outside and inside conditions," then, I refer to the conditions that exist naturally in the localities named, and to the conditions that would exist in mills in those localities heated to 75°, respectively. Take for example Charlotte, N. C., the month of January shows a mean dry bulb temperature of 41° F., with a relative humidity corresponding thereto of 71.6% and a cotton regain of 9.5%; during July the mean dry bulb temperature is 78° F., the relative humidity 75.1%, and the regain 9.6%; from this data showing outside conditions, inside conditions are calculated by considering the January temperature raised to 75° without the addition of moisture, in which event, the air would be dried out as it were, the relative humidity dropping to 22.6% and the regain to 3.7%; in July there is no change, because the outside temperature is above the minimum of 75° upon which the table of inside conditions is based. And so, it will be seen that the table of inside conditions represents conditions that would exist in a mill in any of the localities mentioned if they were not equipped with a humidifying system and an artificial atmosphere maintained therein. It is not to be supposed for a moment that the temperatures inside the mills will not run higher than the conditions taken, because the heat due to the running of the machinery must be taken into account; at the same time, for purposes illustrating climatic conditions this need not be considered.

In Table II., wherever the mean dry bulb temperature is over 75°, the amount is inserted in the tables; where the dry bulb temperatures have been considered raised to 75°, however, in order to make the tables appear clear at a glance, the 75° figures are omitted. Chart II., graphically illustrates the conditions corresponding to Table II.

Any one desiring to look into the details of these charts,

can refer to Tables I., and II., from which the charts are plotted. This discussion, however, can best be conducted on a basis of the charts, and therefore, they alone will be considered:

(1) It will be noted that the Charts I., and II., plot outside and inside cotton and worsted regain conditions; Chart III., plots outside temperatures only.

(2) It will be noted that in Chart I., showing outside regain conditions, all the curves lies above the 7½% line, which is the proposed U. S. Standard. The significance of this fact is its explanation of the reason why textile products all gain weight by absorbing moisture after they are shipped from the mills; for, after they leave the mills, whether yarns or cloths, they are generally stored in warehouses or other places without artificial heat, so that the regain conditions in those places are identical with those for outside conditions as shown in Chart I. This is rather remarkable when it is considered that this is true of all the manufacturing localities given, the only exception noted on the chart is Phoenix, Arizona, which lies well below the proposed standard of regain and which was inserted by way of contrast, it not being a manufacturing district in any sense and selected for illustration only because it was one of the dryest climates known.

One of the things that arrests one's attention in this Chart is the fact that the curve for Bolton, England, is one of the most irregular curves of the lot, starting at approximately 14% cotton regain in January and dropping below 10% in July, then zig-zagging around back up to 12% in December, all of which explains, as previously stated, the extreme care with which British manufacturers endeavor to control artificially the conditions existing in their factories.

Bombay, India, represents a very interesting curve because it is one of the most even and uniform curves of the lot, barring the conditions in the fall.

(3) It is safe to assume that textile materials may be shipped anywhere in the United States within the manufacturing district without loss of weight, but with a decided gain in weight, up to a probable average of even 8 or 9% regain,—less a certain amount due to the care with which the goods are packed, the density of the package, and the length of time stored.

This also explains why converters purchasing goods such as print cloths are able to buy the product of the average mill made of normal weights; and then, after all the stretching the materials undergo in finishing and printing, the goods are still sold for normal weights, and actually tip the scales to those weights too! In other words, the average mill does not maintain a uniform and high enough standard of regain in manufacture, so that others get the benefit of

the regain that the manufacturer should retain. It is quite clear that the manufacturer is entitled to the standard of regain upon which the consumer ordinarily buys the goods, and those who handle them in the intermediate stages are not the ones entitled to it. How much this amounts to, some of the mills having made this class of goods for the past forty years can reflect upon in sack cloth and ashes. When it is considered that the average mill maintains atmospheric conditions corresponding to a cotton regain of only 4 to 5%, as shown in Chart II., for many months in the year, the amount of loss can be roughly approximated. Even in mills equipped with humidifying system, it will be found how surprisingly low the regain conditions are maintained,—a statement that is well worth any mill man's attention who doubts it, to the extent of testing the conditions existing in his own mill with a sling psychrometer straight through a period covering a year. There are few humidifying systems that have been installed in the past that are adequate either in inherent design or in amount of installation, and the conditions in which they are kept either by not being properly and regularly cleaned out and thereby kept up to a standard of highest efficiency, and lack of Automatic Regulation,—all these conditions in a large majority of instances explain why humidified mills, with undoubtedly better atmospheric conditions than unhumidified mills, still fall so short of what is desirable and necessary.

(4) It is interesting to observe the comparison of the charts of outside and inside conditions, noting how the irregular and erratic curves of outside conditions become, in all mills wherever they may be located, practically uniform and parallel to each other, differing from another only in position and not in shape or direction; one climate simply possessing a little more or a little less moisture than another, otherwise all alike. The only exception is Bombay, India, which overtops the lot and which is the most uniform of them all, although still varying 3% in regain within the space of the three short months of August to November! All of which emphasizes the fact that no climate is an ideal climate for manufacturing, and that the best manufacturer must pay close attention to atmospheric conditions in his mills.

(5) By observing the chart of inside conditions, a casual observer is likely to remark that there is enough regain in the summer months and that humidifying is unnecessary; this would be true were the natural climatic conditions the only considerations affecting the problem; but they are not, for the heat of the machinery and the "hot house effect" of the mills in absorbing heat and holding it during the day, causes the temperature to go higher in summer than the 75° limit upon which Chart II., is based, so that the apex of

the curves of regain shown in Chart II., is flattened and the parts of all the curves shown above the standard of 7½% line are dropped down at least to it and generally below it. And so, humidifying is necessary all the year round, from the standard of regain alone,—not to mention the fact that humidifying helps by air cleansing and by cooling.

(6) It is not out of place to point out that many mills which condition their cops for weaving in winter don't find it necessary in summer; for, as the curves show, in not properly humidified mills the average regain will probably be about 4% in winter and 5 or 6% in summer,—making just the difference between filling that runs well and filling that does not. This general statement, however, is to be checked up in detail in each mill, because in many mills it will be necessary to condition the cops the year round,—I refer particularly to mills that get very hot in summer; as a general proposition, mills that run cold require less conditioning both of air and of materials, than mills that get correspondingly hotter.

(7) It is merely of academic interest to note how similar in appearance the regain curves of inside conditions in Chart II., resemble the outside temperature curves in Chart III.

In conclusion I may be pardoned for calling attention to the fact that by Automatic Regulation, in a chart of inside conditions in mills located anywhere, the inside regain conditions instead of appearing as in Chart II., become straight lines parallel to the 7½% line of proposed U. S. Standard, and all of them in any locality, indeed, can be super-imposed upon that line if desired,—See Chapter VII, for examples of charts and records showing results achieved, not results taken by us or by our men but samples of daily records by the mill management and sent us months after our men had gone after completing the installation of the jobs.

V.

AIR CONDITIONING

When entering this field, several years ago, I was puzzled to find a word that would embrace this whole subject: in casting about, I finally hit upon the compound word, "Air Conditioning" which seems to have been a happy enough choice to have been generally adopted. The idea was suggested by the use of the term "Conditioning" in the treatment of yarn and cloth, and even of raw materials before manufacture.

In this country, it has been largely the custom to consider the heating plant a necessity in a factory and to prepare for it accordingly in the design of the building, considerable thought being given to it and oftimes to ventilation; moistening, however, has generally been of secondary consideration, often regarded as a luxury, and, given scant, if any, study in the original design of the plant, although strange to say the latter is of as much importance as the former to the health and comfort of the operators, and of far greater consequence in manufacturing considerations. Many times heating and humidifying equipments work against each other, and until recently no systematic effort has been made to co-ordinate them by which changes in the one cause corresponding changes in the other, the whole functioning according to a predetermined and prearranged standard.

Awakened interest in the problem and increasing knowledge of the subject, with correspondingly greater appreciation of its importance, are bringing about a more rational way of going at it however; and so in the case of many new mills heating, humidification and ventilation are considered together, and decided upon with the other engineering questions involved in the preparation of the preliminary plans, to the end that the equipments decided upon may be incorporated in the working plans with the obvious advantages attendant upon such a method of procedure.

This general subject can best be approached by a rapid sketch of the attention it has received abroad where it has not only been the subject of painstaking investigation but of statutory regulation:

Air Moistening and Heating.

Sir Benjamin Dobson, the most eminent English authority on the subject, has expressed particularly well the underlying principle that governs artificial air moistening:

"The question of humidity is intimately allied with that of temperature, and in manufactories it is

first necessary to fix the temperature at which the work-room shall be kept, and then to make such arrangements that this air may be supplied with the amount of moisture sufficient to make the air soft enough for the comfort of the work-people and the conditioning of the fibre and to render the atmosphere a sufficiently good conductor to subtract the extraneous and superfluous electricity."

At another time he described the scope of the investigation of the Cotton Cloth Factories Act Inquiry Commission appointed by the Government to look into the operation of, and the fitness for the purpose of the Cotton Cloth Factories Act of 1889 (see page 1336); the lines laid down cover so completely the subject in its larger sense that it may well be taken as the definition of Air Conditioning:

Air Conditioning.

"Now from May 11th, 1896, to January 26th, 1897, a Commission appointed by Parliament sat to take evidence with respect to the working of the Act (Cotton Cloth Factories Act), and this Commission examined a number of witnesses of all classes connected with the industry, and also professional men interested and experienced in the working of the Act. Naturally the question for investigation would be divided into certain branches, as for instance, say:

First.—The amount of humidity required for successful manufacturing.
Second.—The temperature of the work-room.
Third.—The comparative purity of the atmosphere in the rooms.
Fourth.—The means for obtaining the humidity.
Fifth.—The means of ventilation.
Sixth.—The method of heating.

Mr. Joseph Winward, a mill manager of Bolton, England, has well stated the consideration affecting what he terms humidification. These considerations are:

(1). Humidity employed in the manufacture.
(2). The materials that are to be manufactured.
(3). The possibility of bringing about conditions suitable to both.

Summarizing then, apparatus for air conditioning should provide means for—

(a) Heating.
(b) Air Moistening.
(c) Ventilating.
(d) Air Cleansing.
(e) Air Cooling.
(f) Automatic Regulation of humidity and temperature to a predetermined standard.

(For heating see pages 376-403, Vol. II.)

Obsolete Methods.

In the earlier days of textile manufacturing artificial humidifying was usually accomplished by one of two methods:

(1) Live steam, which was generally introduced by the use of so-called vapor pots; these vapor pots were simply receptacles open to the atmosphere into which live

steam was blown from suitable supply pipes, and were provided with waste water outlets for removing the drip that condensed within. In some instances, however, the steam jets discharged directly into the rooms.

(2) The ancient and time honored method of degging, which was simply sprinkling the floor with watering pots.

For obvious reasons no attention whatever need be given either of these methods as both are obsolete and out of date and used but little except in emergencies as temporary makeshifts pending the completion or installation of a more modern type of apparatus.

Modern Methods.

Naturally before taking up modern methods of air conditioning a comprehensive view of the requirements of the case is in order, with a brief consideration of its possibilities, in detail.

In describing other types and systems of apparatus, the limitations of this volume preclude more than rapid sketches and generalities; for, as this volume is of somewhat of an advertising character, it has seemed better to devote the space to general information relating to the whole subject and to detailed information as to how it is accomplished by the Cramer System and by the Cramer Regulator.

Air Moistening.

There are obviously so many ways of moistening air, each having its good and its bad points, all so intimately bound up with other considerations affecting the problem of air conditioning, that it seems best to approach that part of the subject by a discussion of the other features entering into it.

Will the Enlargement of Volume of Air by Vapor Produce a Plenum in a Room Tending to Prevent Leakages of Outside Air.

It has been sometimes erroneously supposed that simply moistening the air in factories tends to prevent the infiltration of outside air. The increase in volume certainly will not do it, for though the mixed air and vapor do occupy a space in proportion to the sum of the elasticities of both, yet that increase is small; for instance, the enlargement of a volume of dry air by the addition of saturated vapor is only 2½% at 70° temperature; and in the case of air with some moisture already in it and the increase to only a moderate percentage of saturation, as is usual in a mill, the increase in volume would be less than 2%,—practically nothing for the purpose under consideration.

Will the Enlargement of Air by Increase of Temperature Do it.

Again, the tendency of the friction of the machinery and the body heat given off by the operatives is sufficient to raise the temperature and to increase the volume in spite of the cooling due to evaporation of the moisture added, but that results in increase in volume of only 1% for approximately 5° rise of temperature.

Will the Addition of Vapor to Dry Air Increase the Barometric Pressure and Tend to Keep Outside Air from Entering?

The weight of a cubic foot of air added to the weight of vapor at any temperature and any percentage of humidity gives the total weight of the mixture, so that adding moisture increases the weight undoubtedly; even then, however, the increased weight must be divided by the increased volume due to the addition of that vapor; so that the apparent increased weight, which is by comparison slight, becomes by correction negligible compared to outside air. Furthermore, if the air is increased in temperature by the friction of the machinery, in spite of the cooling due to evaporation of the moisture added, as is often the case in spinning rooms, the weight of the mixture is to be still further diminished by dividing it by the increase of volume due to increase in temperature. These considerations, however, do not affect barometric pressure, for barometric pressure is a function of the weight of the whole column of outside air miles high, and so the slight variation of weight in a few feet of air in a room due to changes in humidity or temperature are by comparison insignificant, and the barometric pressure inside and outside will be the same.

The Practical Effect of Winds, the only Factors Worth Considering in Plenum Calculations.

But more than all these theoretical considerations, the gentlest wind against the side of a building will get enough air through, except with double windows, to require a perceptible plenum, or pressure within, to counteract it. This can be tested in almost any mill. The effect of heat and cold from the outside will be to disturb atmospheric conditions along the side walls of rooms, but these will be minimized by bringing in air for ventilation enough to cause tendency for leakage outward instead of inward.

Effect of Opening Windows for Ventilation.

With even a dead calm out of doors, the inside and outside air will diffuse and mix through open windows to an extent as to render humidification very difficult if many windows are open, and above all if wide open.

And with even the faintest breeze blowing, one that would be termed "light" or the very least recorded by the Weather Bureau, the problem becomes very different; with one but little more perceptible and the least that would be termed "gentle" it becomes practically impossible.

Consider for example a window, of which the transom alone is open; the average transom in an "eight foot bay" is five feet wide and four feet high, 20 sq. ft. of opening. With all open on each side, and assuming that the wind blows in one side and out the other, it will be seen by calculation that

in a mill 75′-0″ wide inside and an average height of story of 16′-0″, with all the transoms open the faintest breeze, one with a velocity of but one mile an hour, will change all the air in a room ten times an hour! Transoms 1-3 open will change it about 3 times per hour, or every 20 minutes. In wider mills, the effect will be in proportion. And with stronger winds but still the lightest, gentle, 3 miles per hour, the change will be thirty times an hour! With every other window open and the alternate ones closed, the effect will be one-half, and other combinations in proportion.

Again, by comparison, the average mill damper to a hot air flue is 24″x24″, or 4 sq. ft., so that each transom is five times the area of a damper opening, and, as the air velocity through a damper opening is 36,000 feet per hour (600 feet per minute) it requires a breeze less than one and one-half miles per hour that a transom may equal in ventilating capacity one damper.

And so the practice of some mills in throwing windows wide open promiscuously is bad to say the least. It is clearly worth while to go to a reasonable expense to provide for ventilation in other ways coupled with humidification. It is not claimed that it will be "reasonable" to go to the expense of installing and operating an apparatus adequate for ventilating under all conditions; there may be some very few days when natural ventilation by opening windows will be necessary to help out.

That, however, can be accomplished by a little care and in such a manner as to cause but little trouble. The proper way is to open the whole row of transoms, each the very least that will suffice; one long narrow opening made in that manner will be found more effective and give less annoyance than any other. Not only does the heat escape uniformly throughout the length of the room, but also no large random openings allow the dry outside air to bore large holes through the moist air inside, nor allow large volumes of moving air to blow down the "ends" in spinning.

A Suggestion Regarding Windows.

Many operatives in mills seem determined to look out through windows and will sneak windows open in even cold or wet days in spite of overseers. It appears, however, that it is a mental attitude more than anything else, and those who are the most set on being able to look out, least often really avail themselves of it. It has been found easier to give them an opportunity to do what they think they want in this respect than to try to break them of the habit. Mills, therefore, who have glazed their windows with ribbed or other translucent or opaque glass, can change to clear glass in the lower sash to advantage, leaving the glass ribbed above the height of the eye. Experiments along this line indicate that most of the difficulty in keeping

the lower sash of windows closed, can be obviated in this manner. It may be argued that one can permanently fasten the lower sash down, but would it not keep the help more satisfied to have them fastened down and still cater to this notion on their part. Any one who critically watches operatives in rooms where clear glass is used in the windows will quickly realize that there is little or nothing to be feared from their wasting time and loafing while looking through windows. About the only times they pay much attention to it is to take a look just before they are going out at quitting times to see the state of the weather. The principal advantage of opaque or ribbed glass, therefore, is not on account of its better diffusing the light and preventing sunlight and shadows along the sides; a row of clear glass along the bottom will not materially affect the problem and so can just as well be used as not.

Effect of Differences of Temperatures Inside and Outside on Heating and Cooling Problems.

Radiant heat has the remarkable property of passing considerable distances through dry air without warming it appreciably, so that air is not warmed by the passage through it of radiant heat but largely by contact with surfaces that have absorbed the heat. It should be remarked however, that moist air is appreciably warmed by radiant heat as heat is readily absorbed by the moisture in the air. The heating effect of sunlight is, therefore, greater in moist atmospheres than in dry ones.

The amount of heat transmitted from outside to inside and vice versa may be made clear for this purpose by saying that each square foot of window glass will heat or cool approximately one and one-quarter cubic feet of air per minute to the temperature outside; and outside brick walls one-fifth as much.

The Effect of Large Windows.

The effect of large windows therefore is to make the heating problem greater in winter, and the cooling problem more difficult in summer. Still it is only proper to add that the advantage of increased light more than compensates for these disadvantages in a manufacturing plant.

How can Plenum be Maintained.

Obviously, to cause a leakage outward the air must be blown in by fans and a plenum maintained; this can be accomplished either by one central equipment and distributed through tunnels, ducts, and flues, or by a number of fans suitably disposed around the walls of the room: it is clear that the latter plan is more economical in the use of power and furthermore permits of surcharging the air with moisture in the shape of a fine vapor-like spray,—a very desirable effect in conditioning air on a commercial basis, as will be seen later.

Ventilation by a central blower system is effective but expensive in power consumption.

Ventilation by Humidifiers.

Ventilation by small propeller fans interspersed at frequent intervals along the walls especially combined with humidification is both effective and efficient. One-sixteenth of one mechanical horsepower will move 50,000 cubic feet of air per hour under such conditions.

Ventilation with atomizers or so called "Turbos" is negligible, for with an atomizer using 1½ cubic feet of free air per minute, or 90 feet per hour, 550 of them would be required to do the work of one of the small fans mentioned.

Extent of Body Heat from Operatives.

No doubt it appears far fetched to devote a paragraph to this subject, although every one is familiar with the heating power of living beings when shut up in a close room, even though there be ventilation enough to prevent oppression. The importance of taking it into consideration will be apparent when it is stated that each human is supposed to consume food to the equivalent of 2,500,000 to 3,000,000 gram-calories per 24 hours, and on an average that 2,400,000 gram-calories of heat are lost during the same period. Now, that heat loss equals 2,400 kilogram-calories in 24 hours, or 100 in one hour, which in turn equals 396.8 B.T.U. per hour; as one horsepower is equivalent to 2545 B.T.U. per hour, the body heat of an adult is equivalent to a little more than one-seventh horsepower! The heating effect of say one hundred operatives in a room is by no means a negligible quantity. And for that matter the air moistening effect is appreciable considering that each one is breathing out 15.6 cubic feet of saturated warm air per hour; it is true that this is somewhat of an academic observation, but not so much after all if one observes the moisture thus imparted to the air in a crowded room as it condenses on window panes during cold days.

Heat from Machinery.

The amount of horse power consumed by machinery can easily be calculated, or better still definitely ascertained by testing. The heating effect of converting that amount of power into work can be ascertained by a simple calculation:

One horse power equals 33,000 foot-lbs., which divided by 778 foot-lbs., the mechanical equivalent of one B.T.U., gives 42.5 B.T.U. for each horse power per minute, or 2545 per hour. It may be roughly stated that the evaporation of one lb. of water per minute will absorb the heat liberated by 25 horse power in frictional heat.

Whether evaporated in the atmosphere, or in a boiler, the same quantity of heat is required to evaporate a pound of water; in the boiler, the heat is supplied by the combustion of fuel, whereas in atmospheric evaporation the heat is ab-

stracted from the atmosphere itself. And so, cooling by evaporation in summer is exactly comparable to heating in winter by steam, and both obey the same law. Under a good boiler, 1 lb. of coal evaporates about 9 lbs. of water per hour.

Cooling by Evaporation.

A humidifier evaporating 3 gallons of water per hour (3x8-1-3 equals 25 lbs.) does as much cooling as nearly 3 lbs. of coal would accomplish in steam heating. A mill with 100 such humidifiers then would be cooled to the same extent that the burning of 1½ tons of coal would heat in 10 hours: this is a highly advantageous showing in summer, but a loss in winter as it apparently adds that much to the duty of the heating plant. And yet paradoxical as it may sound, such is not the case. The apparent loss is quite made good by the increase in heating effect by increased sensibility to heat of one in a room in which there is considerable moisture in the air. As dry air tends to dry rapidly the moisture thrown off through the pores of the skin and thereby to rapidly cool the body, in a dry atmosphere a higher degree of heat must be maintained to compensate for it; and conversely, a lower degree of heat can be maintained with an equal degree of comfort when the air is moist and there is a lesser surface cooling of the body by evaporation. A mill without humidifiers should maintain at least 5 degrees warmer atmosphere than one with them in winter.

Again, the cooling effect can be shown in another way. The saturation of air by evaporation will cool it to the wet bulb temperature of a hygrometer provided the air be not moving, or to the wet bulb temperature of a psychrometer if the air be moving at the requisite velocity. And so, an ordinary thermometer held in the spray issuing from a humidifier will be found to be cooled to psychrometric temperature for whatever percentage of relative humidity the air showed entering the humidifier. It is upon this simple principle that rags and wickings are done away with in the Cramer Automatic Regulator; the naked wet bulb is simply placed in the draft of air from an atomizer in the wet bulb cabinet of the regulator.

As noted elsewhere, 1 B.T.U. will raise 1 lb. of water 1° F. from 32°; the specific heat of air is .2374; therefore 1 B.T.U. will raise 1 divided by .2374 or 4.2 lbs. of air 1°, which multiplied by the number of cubic feet of air in one lb. (12.4) gives nearly 52 cubic feet of air that 1 B.T.U. will raise 1° in temperature. But as the vapor in it must be heated, 50 cubic feet is usually considered an average figure. It is again to be emphasized that this data can be used equally in heating or in cooling calculations. For example,—

As 1 lb. vapor at 0 lbs. gauge pressure condensed gives off 965 B.T.U. it therefore equals warming about 48,000 cubic feet of air 1°; and conversely, 1 lb. evaporation at

80° temperature will cool air at 80° for instance, 965 + 132 x 50 equals approximately 54, 000 cu. ft. 1°. And so a spray humidifier evaporating 3 gallons, 25 lbs., of water per hour would cool 54,000 cu. ft. of air 25°, but the temperature of the air would not be reduced by that amount owing to the heat given off by the machinery, that from the outside walls and windows, the body heat of the operatives, etc.—still, the cooling effect is actual and real so far as preventing the rooms from getting overheated from the causes mentioned.

Cooling by Expansion of Gases.

Refrigeration or cooling by the expansion of gases, is of interest in this discussion only because some people vaguely suggest artificially cooling the water and thereby cooling the air to the extent of condensing out moisture in "dog days," thereby lessening the humidity. This is economically feasible only when cool water is obtainable from a pond, or river, and does not have to be artificially cooled.

Refrigeration.

The basis of refrigeration is the number of pounds of ice melted into water at 32° F.; large plants are rated in tons of ice melted. The cooling effect of ice is largely the latent heat of the fusion of ice, 142 B.T.U.—just as in heating by steam, advantage is taken of the latent heat of evaporation, 965 B.T.U.

Ammonia and other volatile gases are generally used in ice machines except on shipboard where compressed air is used, for a number of considerations unnecessary to state here.

It is this fact, that has caused claims to be made for the cooling effect of the expansion of compressed air used in the atomizer type of humidifier. Theoretically it can be figured out that cooling can be obtained, but practically the amount is negligible as can easily be ascertained by holding a thermometer in the jet of air issuing from such a humidifier with the water turned off so that compressed air only issues from the nozzle; the thermometer will not fall one-tenth of one degree!

Is Air Washing Necessary to Remove Dust and "Fly" from the Atmosphere.

As already shown, a moist atmosphere prevents the floating about of dust and "fly" to a large extent, 54% by actual test. That this is a great help no one will deny, but that it is equally desirable to get rid of as much of the other 46% is equally self-evident. This can only be accomplished by air washing. That a purely evaporative type humidifier cannot do it is clear upon reflection, nor can one do it that simply sprays into the atmosphere. In the one case, dust will not readily "wet" but will float rather than sink into water, the surface tension of air around the diminutive particles being greater than their mass; and so simply blowing air containing dust over wetted surfaces does not remove

it by any means. In the other case, it is admitted that the mere presence of moisture prevents dust and "fly" to the extent of 54%; but the present consideration is the other 46% that should also be removed. Reverting to Nature for the operation of laws bearing on this work on a scale that makes it authoritative:

One often hears advocates of evaporative types of humidifiers compare their apparatus to Nature's way of accomplishing its work. That depends upon the point of view. If it worked out in practice, one would find sea coast towns impossible localities for manufacturing owing to the excess of moisture that must exist by evaporation from the ocean, if the extent of natural evaporation were anything like that claimed for it; whereas, it is well known that artificial moistening is required in such localities through all months of the year just as in other places, although not quite to the same extent. Again, has not every one noticed the moistening effect of even the slightest shower of rain. Is it not clearly due to the fact that the air has simply been "doused" by the rain? The air has been subjected to a continuous shower of relatively large drops, so that not only was a great surface of water brought into contact with the air, but the water has driven or beaten through it with great force, and continued long enough that each particle of air was sure to be wetted and washed again and again. The dust particles were therefore not only vigorously wetted but were both taken up by the rain drops and beaten down to the ground. And so, is not the logical way, in fact does it not appear the only way, to get rid of "fly" and dust with its countless millions of bacteria many of which breed disease, by working along the same lines? Does it sound reasonable to assert that no dust will be threshed out of the cotton in process of manufacture, no bacteria will exist in the atmosphere merely because the atmosphere be kept moist? In fact, is it not well known that micro-organisms multiply and propogate under conditions of warmth and moisture? And therefore would a room be healthful long that depended upon "keeping them down" instead of "getting them out?" Is it not the logical course to "douse" the air with a fine spray under considerable pressure,—a fine spray to accomplish in a short time what Nature takes more time to do, and under pressure to get the velocity and beating effect that rain drops have after falling such a distance? And too should not some means for forcing through a large quantity of air be used for the same reason,—to treat more air with a given amount of water in less time? And then after letting the moistened air escape into the room, should not the circulating water be conducted away where it can be filtered and the collecting receptacle regularly washed and cleaned out?

Air Moistening Devices.

In General. Whereas, the percentage of relative humidity may be raised by lowering the temperature of the air, the amount of actual or absolute humidity measured in grains per cubic foot cannot be increased except by evaporation. Air moistening then is only a matter of evaporation, and the most effective moistener pure and simple is the one that presents moisture to the air in quantity and condition to be most readily evaporated. There are three ways of doing this; by driving the moisture through air, by blowing air through the moisture, and by a combination of both. Atomizers belong to the first class, and evaporative types of humidifiers where the air is blown over wetted surfaces, to the second class. To the combination class belong all humidifiers wherein the air is directed through a cloud of spray and thence over surfaces which condense the spray and vapor and deliver what may be termed dry air; and, those which separate only the coarse particles leaving a fine cloud-like vapor issuing with the moistened air—this surcharging of the air effecting a great increase in capacity.

Anything so primitive as troughs of water extending around the sides, channels of water along the walls, both depending upon natural evaporation and both getting foul and requiring a great deal of attention, hardly seem to need mention, yet it is not out of place to do so, to emphasize the advance over by no means by-gone days in the art.

And methods by which damp basements are maintained and from which ducts and flues either in the walls, the columns, or tubes conduct the damp air into the rooms on the upper floors, it would seem are clumsy ways of doing what could be much simpler effected by a fan and heater system with suitable moistening sprays, all occupying but a very small space comparatively, and with correspondingly less cost for construction and but little more cost for operation.

Atomizers are of two kinds, the plain type familiar to all, and the ejector, or so called "turbo" type; the plain ejector type is of the well known type of device for handling water with steam or compressed air, only instead of quantity of water moved being the desideratum the purpose is to throw but a finely broken up spray of water. In the turbo type of ejector atomizer, the air is admitted to the air chamber in it through tangential openings; it is claimed that the spray issues from the orifice with a centrifugal motion thereby "ballooning the jet" and shortening it up,—a remarkable claim when all other efforts are being directed towards extending the radius of action of humidifiers instead of shortening it up.

Water spray nozzles have heretofore been of both the single and double jet, as they were called; in the one a single

jet of water is broken up on a small pin near the orifice, and in the other there are two jets directed one against the other, one of the jets serving the purpose of the pin. The single jet type being the more durable and efficient, the double jet has been about discarded.

Air moistening is usually accomplished either by a centrally located combination fan, heating and moistening apparatus with suitable ducts and flues for distribution; or, by individual "heads" located throughout the different rooms uniformly and symmetrically placed.

The former is designed to handle fresh air from the outside but with provision for drawing air from some of the rooms and using it over again by mixing it with a suitable proportion of outside air.

In the atomizer types no provision is made for ventilation nor any attempt made to do anything else than simply to discharge spray into the air.

Plain spray types of humidifiers can be used either as inside types, or as ventilating types, both types in the same installation; this kind of head, however, is hardly fitted for ventilating purposes as it depends only upon the inductive effect of the spray of water through the casing to draw the air in and through it. Such heads have good moistening capacity and fair air washing and air cleansing capacity.

Fan types of spray heads are but a further development and evolution of the plain spray type, a fan aiding the inductive effect of the water spray through the casing so that they have large air handling capacity which eminently fits them for combined ventilating and humidifying purposes, as well as increases their air washing and cleansing capacity in corresponding proportion,—coupled with great radius of action and distribution.

A curious combination plan, effective as far as it goes, is used abroad whereby each room has one or more fans as though it were a central outfit but instead of delivering through ducts and flues they deliver at right angles through long trough-like discharge pipes. Owing to the resistance offered by the discharge pipes, they are subject to the same disadvantage in the power question that the regular central apparatus labors under, being compelled to use blower types of fans instead of the lighter running propeller type.

In all types of air moistening devices, hot water can be turned in to advantage in winter time, but unless automatically regulated should be watched very closely in medium weather, for a room will quickly overheat with this addition to the regular heating system.

By the law of diffusion of gases, the outside and inside air will tend to mix and become an average, the change taking place through the slightest cracks and openings; and for the same reason the localized warm and cold places, wet and dry places throughout the rooms will tend to disappear, but

a considerable time element enters into it,—so much so that in rooms where the machinery is driven by individual electric motors, it is found desirable to use some means for keeping the air in motion to secure uniform conditions throughout. In rooms where the machines are driven by belts, less trouble is experienced; but in any case, it cannot be too emphatically pointed out that the practice of shutting off humidifiers individually is a bad one to drop into. Is it not irrational to carefully lay out with great uniformity a number of heads in a room so disposed as to secure the most uniform distribution of the moisture, and then upset it all by shutting off a head here and there according to the whim of someone who takes the notion. The obviously correct method is to shut them all off and turn them all on as required.

Cold moistened air tends to fall, and warm air to rise, obeying the law of gravitation by which the heavier displaces the lighter; on account of which, humidifiers should draw inside air from as near ceilings as possible, and discharge it well up and radially as far as possible.

Water Required for Humidifying.

Many fanciful problems can be worked out under different conditions for determining the amount of water required for air moistening, but the results are unsatisfactory on account of the time element. It is very simple, for example, to say that on a cold clear day with a temperature and relative humidity outside of 30° F. and 50% respectively that such air introduced into a mill maintaining a temperature of 75° and relative humidity of 60% must be heated and moistened up to those figures; and the calculation is simple, too:

Inside Air at 75° and 60%	5.65	grains per cu. ft.
Outside Air at 30° and 50%	1.00	" "
Moisture that must be added	4.65	" "

But who can say that after the air has been raised to the desired standard how long will it remain so and how much additional moisture must be added continuously to maintain the balance. For example, 70 grs. in 10 hours were required in some of the windy fall days of the past year to maintain an average of 6 grains of moisture per cubic foot of space in the Manomet Mills, New Bedford, Mass., even when the outside air itself contained an average of 4 grains of moisture,—the moisture required to be added being only 2 grains! There are too many variables for anything like exact calculations and so it is enough to say that it has been found necessary in actual practice to provide evaporative capacity in the following proportions to meet all the emergencies that arise:

In card rooms, 1 lb. of water per hour for each 1,000 cu. ft. of space; in roving and spinning rooms, 1 lb. to 800 cu. ft.;

in combing, winding and warping rooms, 1 lb. to 700 cu. ft.; and in weaving rooms, 1 lb. to 600 cu. ft.

Capacity of and Power Required to Operate Air Moistening Apparatus.

It is often essential to know the power required to operate air moistening apparatus not only to compare the operating expense of different systems, but also for calculations in the case of old mills where the power available is limited.

That for a Central Station System comprising one or more large fans with pumps and attendant machinery, allowing four square feet per spindle floor space, and stories of usual pitch, is stated by one of the makers of it to require for a 10,000 spindle mill 11 h. p. in winter, 23 in fall and spring and 35 in summer,—the differences being accounted for by the varying amounts of air required to be handled at one season as compared to another, the shift being accomplished by a three pulley rig. Ventilation is also accomplished with this power expenditure.

The Simple Atomizer Type operated with 35 lbs. air pressure requires about three quarters of one foot of free air per minute and delivers about four pints (4 lbs.) of spray per hour, requiring about 1-10 h. p. each. Figuring 60 lbs. of water evaporated as a minimum requirement per 1,000 spindles the same mill would require 150 atomizers, totaling 15 h. p. No ventilation is provided for.

Of the Ejector Type of Atomizer, or Turbo Type, operated with 60 lbs. air pressure consuming one and sixth tenths cubic feet of free air per minute to spray nearly one gallon (6 to 8 lbs.) of water, 75 to 100 nozzles will be required at ¼ to ⅓ h. p. each. totaling 18 to 25 h. p. No ventilation is accomplished or included in this figure.

Of the Evaporative Type of Humidifiers with fan, evaporating, when using cold water, about one gallon (8 lbs.) per hour, 75 heads will be required at 1-5 h. p. each, totaling 15 h. p. If ventilation is to be provided for also, add one-fifth to the number of heads and to the power consumption.

Of the plain Spray Type of Humidifiers discharging two to two and one-half gallons per hour (16 to 21 lbs.) 38 heads will be required, circulating 90 to 100 gallons of water per hour at 125 lbs. pressure, taking 1-5 h. p. each, totaling 7½ h. p.

If Combined Fan and Spray types of Heads are used, each circulating 48 gallons of water per hour at 135 lbs. pressure and having one-sixteenth of one horse power fans each with a capacity of 50,000 cubic feet of air per hour, dispersing 3 to 4 gallons of water per hour (25 to 32 lbs.) 24 heads will be required at .22 h. p. each, totaling 5 1-3 h. p. If ventilating heads are to be used also, one-fifth more should be installed.

For Automatic Regulation ,the power varies from 1 h. p. for 10,000 spindles to 2 h. p. for 50,000 spindles.

In Conclusion.

A consideration of the present state of the art of Air Conditioning and of the possibilities for improvement, leads one to conclude—

(As to Health.)

(1) That air in textile mills is generally both unsanitary and unhealthy on account of excess of carbonic acid gas and deficiency of oxygen; of dust, lint and fly in suspension in the air; and either because of excessive dryness if humidifiers are not used, or of excessive humidity if humidifiers are used.

(2) That air in textile mills generally causes discomfort because of dust; because of either excessive humidity or excessive dryness; because of too much or too little heat; and, because of an excess of carbonic acid gas, and a deficiency of oxygen.

(3) That heating systems in mills are generally adequate and that overheating is the rule rather than underheating. That it is desirable that maximum temperatures shall be prescribed as well as minimum limits of temperature, which shall only be exceeded after reasonably exhaustive efforts from a commercial standpoint have been made to reduce the excessive temperature by cooling, by ventilation, or by evaporation of moisture in humidification.

(4) That humidification is generally adequate for health, for health does not require high humidities. Maximum limits of humidity should certainly not be exceeded, unless the atmosphere outside is distinctly of such high humidity itself that ordinary methods of reducing humidity by cutting off the water supply to the humidifiers is inadequate,—such as in "dog days," for instance.

(5) That ventilation is generally insufficient and inadequate and should be provided on a basis of not less than 600 cubic feet of fresh air per hour per operative (1200 cubic feet would be better still), although there is doubt about requiring such a high standard in many of the older mills that are not fitted for it on account of their obsolete style of construction. A more rational requirement would be to fix a standard of purity of air with reference to the percentages of carbonic acid gas and oxygen, to the dust and "fly" in suspension, and to temperature and humidity; because, in many cases with doors and ill fitting windows, and with no attempt at even natural ventilation through transoms, etc., sufficient outside air does actually get inside many mills to maintain a satisfactory standard of purity.

(6) That air cleansing of the atmosphere in factories is generally insufficient and although it would be difficult to establish a standard, yet something should be done along this line,—such as, for instance, that provision for positive air cleansing should be made, especially in card rooms; and that all rooms should be kept reasonably free from noxious odors.

(7) That the use of dirty, filthy, contaminated or otherwise objectionable water should not be permitted in humidifying systems. All types of humidifying apparatus should be required to be kept clean inside and free from any suggestion or taint of odor, or slime, or fungus growth, all of which will not only breed bacteria favorable to disease, but in the very nature of the case diffuse them all over the rooms to the operatives.

(As to Manufacturing.)

(8) That humidifying capacity is generally inadequate for maintaining a percentage of regain of even as high as 5% for cotton; in the winter time the percentage often averaging as low as 3½% to 4½%.

(9) That heating systems generally overheat, thereby rendering the process of humidification correspondingly difficult.

(10) That humidifying systems of the spray type so often wet down, that but few carders will allow a spray type of humidifier in among their cards even if placed in the alley-ways. This is also often true of atomizer types of humidifiers.

(11) That both evaporative and atomizer types of humidifiers, in particular, are installed too few in number; the humidity under such

circumstances being too low to be of much service except for a little freshening of the air, and for the dissipation of considerable of the atmospheric electricity. They accomplish better results in the winter time, however, when hot water and steam respectively can be used in them to advantage; it being manifestly out of the question to use hot water in the summer time, their performance at that season of the year is not to be taken at all seriously.

(12) That the power required for central station heating, ventilating and moistening systems is so very expensive that even if mill men put them in and use them in the winter time, but few use them regularly in the summer. This is rather a remarkable condition of affairs because the greatest claims made for this type of apparatus are for its summer performance; this statement can easily be checked up by dropping unexpectedly into mills equipped with apparatus of this type when it will be found that the windows and doors are wide open and the apparatus stopped in summer, on all but the hottest and dryest days. Furthermore, the rush of air from the damper openings in such systems, in conjunction with "return duct" installations, is such as to cause considerable annoyance in fine spinning by breaking down the ends. In some mills it is even the practice to close the dampers near frames when the bobbins are filled near to the doffing point.

(In General.)

(13) That humidity and temperature can be automatically regulated and controlled at reasonable cost for installation and at insignificant cost for maintenance.

(14) That the expense of ventilation can be brought within reasonable limits, for fresh air can be supplied to mills at the rate of 50,000 cubic feet per hour with an expenditure of less than one-tenth mechanical horse power; furthermore, that this same amount of air can be humidified as it enters with a like modicum of power; the total power consumption for both ventilation and humidification can be brought within one-fifth to one-quarter horse power per unit of 50,000 cubic feet.

(15) That air cleansing can likewise be accomplished at the rate of 50,000 cubic feet of air per hour during humidification without further expenditure of power; requirement for air cleansing is, therefore, entirely reasonable and commercially practicable.

(16) That a requirement for the regular cleaning of humidifying apparatus is also practical and can be easily provided for by constructions adapted to that purpose, a number of which are already on the market. If cloths or other absorbent surfaces are used in humidifiers, they should be rigidly inspected and changed often that they may not smell or discolor.

(17) That humidifiers which often "wet down" be avoided for the result can be just as economically and efficiently accomplished without it.

(18) That automatic means for regulating humidity and temperature be adopted, thereby eliminating the objectionable features of too much or too little heat, and too much or too little moisture.

(19) That the ordinary type of hygrometer with a wick covering the wet bulb is not accurate and that all official tests should be made with the sling psychrometer, although the mills themselves may, of course, continue the use of hygrometers if they choose.

That all mechanical types of hygrometers, involving physical changes in vegetable or animal fibres or membranes by the presence of more or less moisture, are unreliable and should not be used.

That the best and most reliable type of humidity indicating and controlling device is the wet and dry bulb thermometer type in which the naked wet bulb is cooled directly by saturated or supersaturated air, the latter being preferred as it is inherent in its type that it is self cleaning.

(20) And finally, that attractively retouched cuts showing operation, specious explanations, careless representations as to capacity, cost of operation, etc., and like extravagant claims of manufacturers of such apparatus,should not be accepted as final; but, that careful personal investigation of the actual working of the apparatus itself in mills be made when choosing types.

VI.

CRAMER SYSTEM OF AIR CONDITIONING.

A number of different types of apparatus for this work are manufactured by us so that we can meet the many different requirements that arise. Local conditions sometimes compel the adoption of one type as best adapted to that particular case, although it may not by any means be the best for all around work. In the past seven or eight years that I have been developing automatic regulation, I have carefully gone over the humidifier field and have developed improved machines of the different types in present day use. This was rendered necessary in order to get enough capacity for regulation; it has been the custom in the past, almost without exception, to cut down humidifier capacity to a point that it could not be automatically regulated on unfavorable days to a point of even 40% R. H. By improved constructions and correct figuring, better conditions can be maintained the year through,—not simply on favorable days. And so, we offer not only our own special types of apparatus, but plain spray heads, atomizers and ejector nozzles, and fan heads with evaporative surfaces or with centrifugal sprayers.

My own specific development for this work, however, embraces my well known "Air Conditioners" of both individual and central station types. They may be used separately or in combination, and even with other types of apparatus occasionally to advantage; and any desired standard of humidity, or regain, can be maintained with surprising uniformity.

We are prepared to supply —

Air Conditioners.

(1) **Central Station Apparatus**, whereby any number of rooms in a building can be heated, cooled, ventilated, air cleansed and humidified wholly or partly by one self-contained apparatus located at any convenient point, and the condition of the air in each room regulated independently of that in the others.

(2) **Individual Heads** located in each room to be served, and spaced to secure an even distribution; all connected up in a circulating system and supplied by a pump located at some convenient place, each room being ventilated, cooled, humidified, air cleansed and regulated independently of the others.

Plain Humidifiers.

(3) Spray Heads.
(4) Atomizers.
(5) Ejector Nozzles.
(6) Centrifugal Sprayers.
(7) Evaporative Heads.

With or without Automatic Regulation.

Cramer Air Conditioners.

As previously indicated, the term "Air Conditioner" is used to designate an apparatus accomplishing not only humidification and cooling, but ventilation and air cleansing; also, in the central station type, including heating as a whole, or in part, according to whether it is desirable to install the apparatus to work alone or to work in conjunction with and supplemental to individual heating and humidifying systems in different rooms.

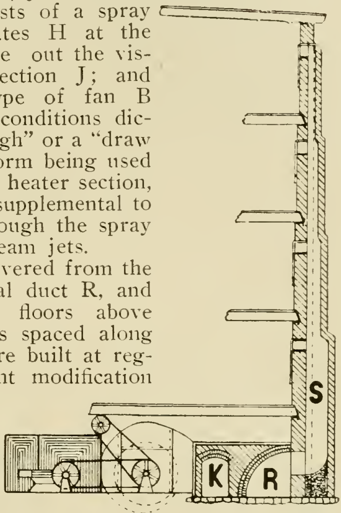
For many purposes, such as public buildings, office buildings, schools, auditoriums and the like, it is recommended that the central station type of apparatus be installed to do the work alone, except in the one possible modification where the apparatus is installed just a little short of what would otherwise be required and small supplemental radiators with automatic control be installed in each room, thereby making the system more elastic and meeting the individual requirements in each room. High cost of operation and lack of flexibility are the disadvantages of this system when installed for operating alone; but, in buildings of the types above mentioned, where the cost for operating is of secondary importance, and where the air in one or very few rooms is to be treated, its fitness for the case in hand should be the determining factor.

In textile and other factories, however, the legitimate use of this type of apparatus is undeniably that of a secondary nature rather than of a primary one; by that I mean that it should supplement the regular heating and humidifying systems in the different rooms, and should be installed of capacity adequate for ventilation only. I am aware that exception will be taken to this statement by manufacturers of this type of apparatus generally, and by some customers who are wedded to it, but the convincing argument in favor of this decision is that very seldom, indeed, if ever, is such an apparatus run the year through on account of the expense of operation. The cleverness of those who explain why the use of the apparatus is not necessary at the particular times that it is found to be shut down does not alter the situation; the fact that the apparatus installed for the avowed purpose of automatically maintaining a uniform condition is frequently shut down on account of the personal and individual opinions of those operating it is sufficient evidence of the fact that there must be some very strong objection to the continued operation of it. And so, under no circumstances can it be recommended to install exclusively in these days of competition an apparatus that is so extravagant in the consumption of power, when the results can be better and more economically obtained by combining both types,—the individual type for the bulk of the work and the central station or other ventilating type supplemental thereto and adequate only for ventilation.

Cramer Air Conditioners, Central Station Type.

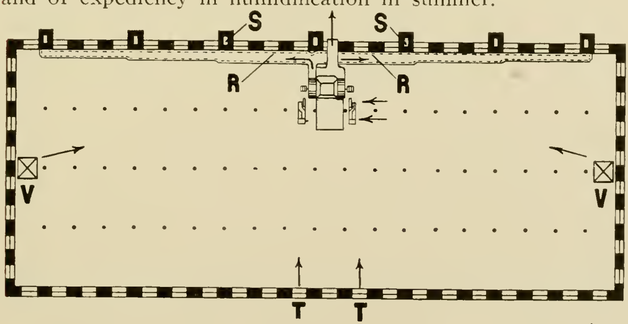
The central station type of apparatus is a development of the old and well known " Blower " or " Fan and Heater " system of heating and ventilating. (See pages 379-403 inclusive, Vol. II.)

In the old form, it consists of a spray chamber F with baffle plates H at the discharge end to condense out the visible moisture; a heater section J; and a blower or exhauster type of fan B according to whether local conditions dictate the use of a "blow through" or a "draw through" outfit, the latter form being used in preference. In lieu of the heater section, or in conjunction with and supplemental to it, the water circulating through the spray nozzles can be heated by steam jets.

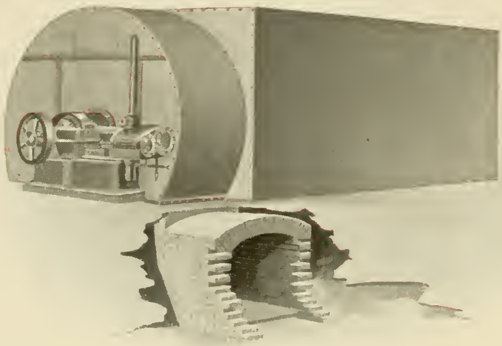


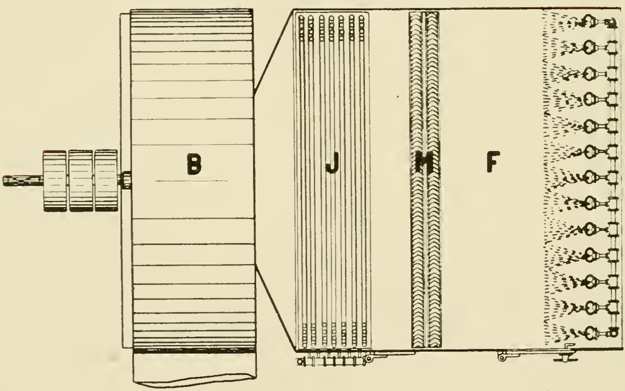
The conditioned air is delivered from the apparatus into a longitudinal duct R, and thence distributed to the floors above through flues S, in pilasters spaced along the walls into which they are built at regular intervals; one frequent modification is the substitution of galvanized iron ducts and flues erected to deliver the conditioned air in the center of the rooms, the logical arrangement because the brick ducts in the side walls get so hot in summer as to considerably heat up the air going through them.

Air is often drawn from upper floors to mix with outside air, as a matter of economy in the saving of heat in winter, and of expediency in humidification in summer.



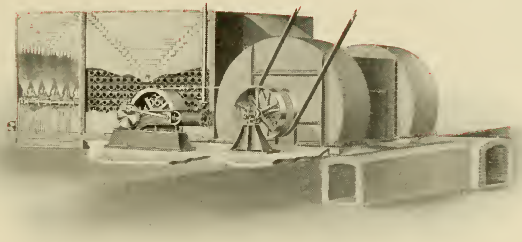
(In the above plan, showing the lower floor of a mill equipped with a Central Station type of apparatus, air comes down through the elevators VV and is mixed with the outside air entering through windows TT, fitted with automatically controlled dampers.)

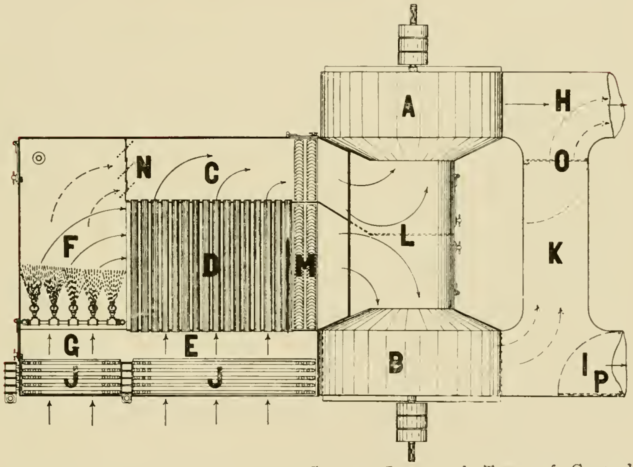




(The above cuts show the old type of Central Station Apparatus heretofore installed, the lower view illustrating in plan, its construction and operation,—described on the preceding page.)

In an equipment of this type, it is obvious that air conditioning in cold weather is simple and effective, and that by controlling the temperature of the moistened air issuing from the apparatus a certain kind of regulation can be maintained based upon the fact that air saturated at a certain temperature contains a definite amount of moisture, which will approxmate that contained in the rooms into which it is discharged under favorable conditions. Such a method of regulation is impracticable in summer, however, as will be subsequently shown, on account of the fact that it is often impossible to





(The above cuts show the Cramer Improved Type of Central Station Apparatus, the lower view illustrating in plan its general construction and operation,—described on page 1416.)

continue saturating the air without increasing the already disagreeable humidity. Not only is such a method of regulation inoperative at such times, but the cooling that is so desirable in hot weather is, of necessity, stopped when the saturation must be stopped.

Yet, so long as the air has any evaporative power whatsoever, so long as it is at less than saturation, there is a possible cooling effect that should be available,—and it is available, too, as my improved apparatus above illustrated will show. Basic Patents have been granted upon such an apparatus, whereby the volume of air to be handled can be divided; when the atmospheric conditions permit of it, all the air is

blown into the rooms, but when no more moisture is permissible one portion is saturated and its cooling effect utilized to cool the other portion, the moistened air being diverted and blown outside while the unmoistened but cooled portion is blown into the rooms.

Referring to the accompanying figures, A and B represent the two fans, each one handling approximately half the capacity of the apparatus. Both draw air from either the outside, the inside, or a mixture of both, tempering it as required by the heater coils JJ, or by equivalent steam jets. F is a spray chamber, through which the air passes directly to the fan B through the cooling chamber D and the baffle plates H. The cooling chamber D has a tube sheet at each end into which sheet copper pipes, or tubes, are inserted, around which the cooled and moistened air passes from the spray chamber F to the fan B, and through which tubes air passes through the front space E to the rear space C and thence to the fan A, being cooled thereby but not being moistened as it has not come into direct contact with the moistened air from the spray chamber F.

There are obviously, therefore, two currents of air, one moistened and cooled and the other not moistened but cooled; by a suitable manipulation of the dampers N, O and P it is clear that the two currents of air can be both directed into the mill through K and the outlet H, or only the dry and cooled current of air into the mill and the other moistened air diverted outside through the exit I.

In the practical working of this Improved Duplex arrangement, the fan B only is operated in winter time, and both fans in summer when a maximum cooling effect is desired; or the same result can be achieved by running both fans at reduced speed.

The very striking advantage gained by the Cramer Central Station Type of Air Conditioners over those of the old style continuous evaporation types is apparent from the following exhibit:

One of the exponents of the latter type claims that in summer time his apparatus will cool a spinning room to within 2° of the temperature of the outside air.

He also publishes a table from which I make the following extract:

Cooling Effect by Evaporation in Humidifiers.

Outdoor Air.			Air Leaves Humidifier.				
Temp.	Hum.	Grs. of Moisture per cu. ft.	Temp.	Hum.	Grs. of Moisture per cu. ft.	Deg. Cooling Effect.	Grs. Moist. added per cu. ft.
85°	60%	7.65	74%	100%	9.07	11°	1.42
80	60	6.65	70	100	7.98	10	1.33
75	60	5.62	65½	100	6.90	9½	1.28
70	60	4.80	61	100	5.94	9	1.14

(Note the amount of moisture added in doing so.)

Just as stated, a cooling effect of approximately 10° is attained, which expends itself in overcoming the heating effect of the machinery, etc., but still managing to prevent a room rise of temperature of over 2° above that of the outside air (assumed, however). Granting all of which, the following condition of affairs exists in the room:

By continuous Saturation of the Air going in, the room air becomes			Remarks.
Temp.	Hum.	Grs. of Moisture per cu. ft.	
87°	67%	9.07	Showing a rise of 7 to 9% Humidity due to the amount of moisture added by continuous saturation, so that if it were desired to maintain any percentage of Humidity under 67% in that room it would be impossible.
82	68	7.98	
77	69	6.90	
72	69	5.94	

Conceding a better cooling effect still, the result becomes worse, as the following table shows, assuming that the apparatus is capable of holding the room temperature down to that of the outside air, with no rise of temperature at all:

By continuous Saturation of the Air going in, the room air becomes			Remarks.
Temp.	Hum.	Grains of Moisture per cu. ft.	
85°	71%	9.07	Showing a rise of 11 — 14% Humidity due to the amount of moisture added by continuous saturation, which is worse yet, for this increased cooling effect has brought about a condition of affairs whereby maintaining less than 71 — 74% is impossible.
80	73	7.98	
75	74	6.90	
70	74	5.94	

Deductions.

And so, it is evident that an apparatus continually saturating the air, has the fatal defect of so increasing the humidity that with even a reasonable outside temperature and humidity, the maintaining of anything except the highest humidities is impossible.

Also, that mixing inside and outside air only makes matters worse, as it gives the equivalent of a still warmer and more moist outside air.

And finally, it is obvious that the principle of utilizing the evaporative power of the air to cool, but discontinuing the saturation of the air delivered to the room when the inside air has reached the critical point, is the correct principle,—the one covered by the Cramer patents.

Cramer Air Conditioner. Individual Type.

(Belt Driven.)

(Electric Driven.)

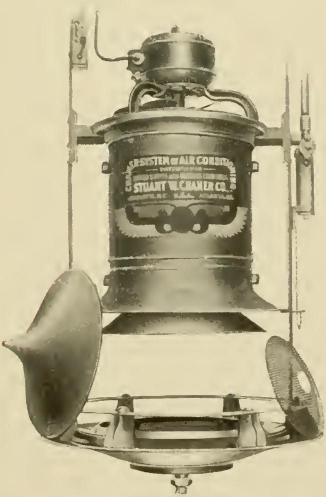
These heads represent the only material advance made in the individual type of humidifier in many years. Prior to their advent upon the market, galvanized iron or any such material was good enough for humidifier work; the permanence of our seamless drawn copper sheet metal work, however, has caused others to copy. This is even more true of its well known feature of accessibility for cleaning, for now every one makes some pretense to that feature. Our first heads of this type had split, or sectional, casings; but that construction was discarded because of their so quickly working loose and out of shape; as soon as we hit upon the present construction, we threw out and replaced the old unsatisfactory split casings in such mills as we had installed them.

The fans on these heads practically double their humidifier capacity, and increase their air cleansing capacity six to eight times!

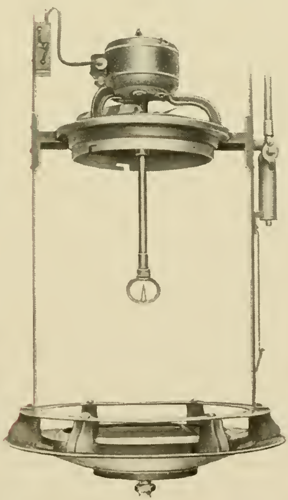
One remarkable feature peculiar to these heads is that the fans can be stopped, the upper casing lowered, and they can be run as plain spray humidifiers; and so, by simply running the pumps, they can be automatically regulated to maintain conditions over Sundays, etc.

(Upper casing lowered)

(Lower casing raised)

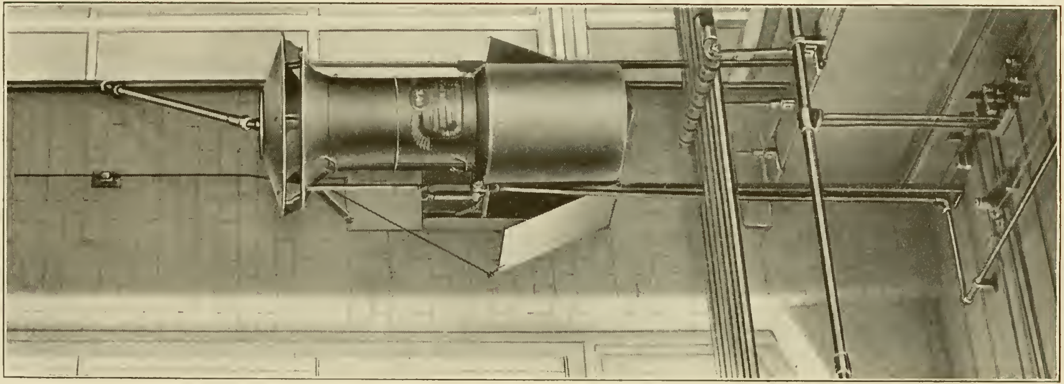


(Cones removed)



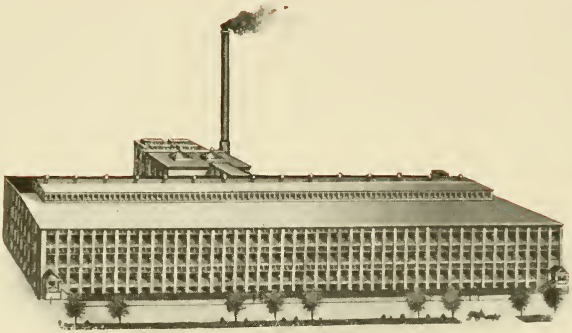
(Completely opened up)

As shown in the accompanying cuts, these heads can be used to ventilate with as well as to air moisten, etc. In fact, the ventilating heads are termed Type W, and the others for inside work only, Type I. Both can be used together in the same rooms to obvious advantage.

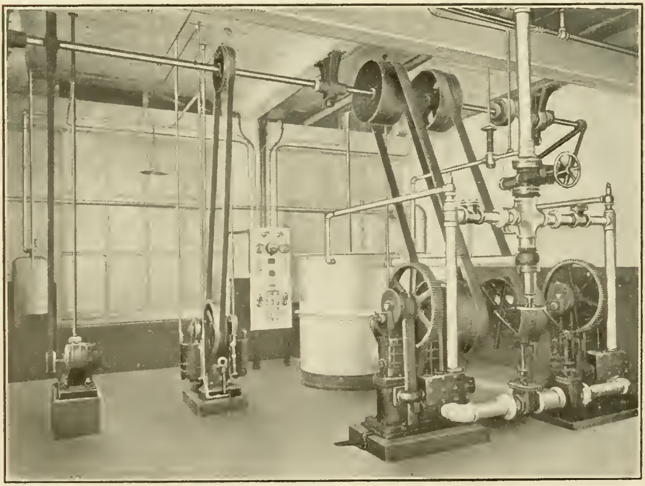


The remarkable capacity and other performance of these heads hardly seems compatible with their equally remarkable efficiency and economy of operation,—all of which, coupled with their reasonable cost warrants again repeating the statement that they represent the most material advance in this art for many years.

(A view in Spinning Room of Manomet Mills, showing Cramer Air Conditioners, Type I.)



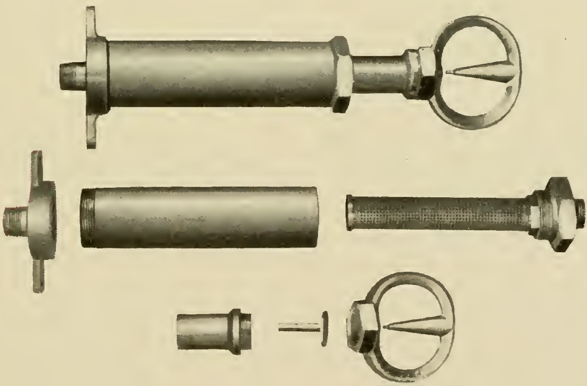
(The No. 2 Mill of the Manomet Mills, New Bedford, Mass., a modern 75,000 spindle mill making combed yarns; in which the Cramer System of Air Conditioning is installed,—the mill in which the accompanying photographs were made.)



(A view in Air Conditioning pump room of Manomet Mills, showing the high standard of equipment installed.)

Cramer Spray Humidifiers.

(The general type of these heads is so well known that the accompanying cuts make quite clear the improvements in construction whereby they are now so easy of access for cleaning and getting at the nozzle. Notice in the cut below the solid design of nozzle, the removable standpipe, etc. All sheet metal parts seamless drawn from sheet copper, no nozzle adjustments,—all contributing to simplicity, durability, accessibility and reliability.)



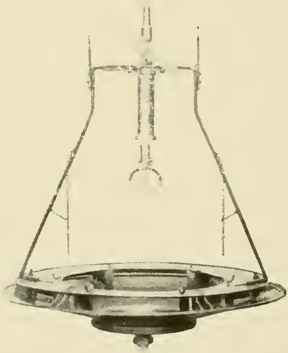
(Cut showing nozzle and strainer used with these humidifiers and parts comprising the same; a different strainer but the same nozzle is used in Cramer Air Conditioners.)

Those opposed to spray humidifiers allege that they moisten and even "wet down" but do not truly humidify. That is true only when the humidifier is forced beyond the capacity of the air to evaporate the amount of moisture thrown out;

(Upper casing down.)

(Lower casing raised.)

(Cones removed.)

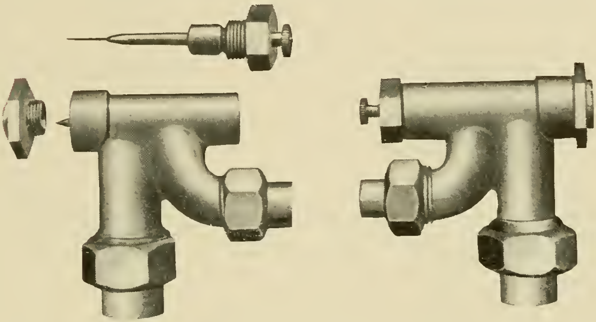


(Completely opened up.)

when properly "set" and operating normally, the millions of tiny globules comprising the spray offer such large area as to greatly exceed in the surface of water presented to the air for evaporation that of any evaporative or other type of humidifier,—hence, their large capacity compared to other types. When fans are added, as in Air Conditioners, thereby forcing the evaporation of more spray than could otherwise be evaporated by comparatively still air, it is seen at once why the superiority of our fan types of heads. Other conditions remaining the same, evaporation proceeds in proportion to the surface of water and to the amount of air exposed to it: whether the surface is a wet rag or the aggregated surfaces of millions of tiny globules is immaterial. As to air cleansing effect (see pages 1403-4), one must not con-

found a mere spray nozzle of the centrifugal, atomizer or ejector type, with a spray humidifier having a casing wherein the air is washed free from dust, etc., which dust is carried off in the return water and is settled, filtered and cleaned out at stated intervals.

Cramer Ejecter Type of Humidifier.

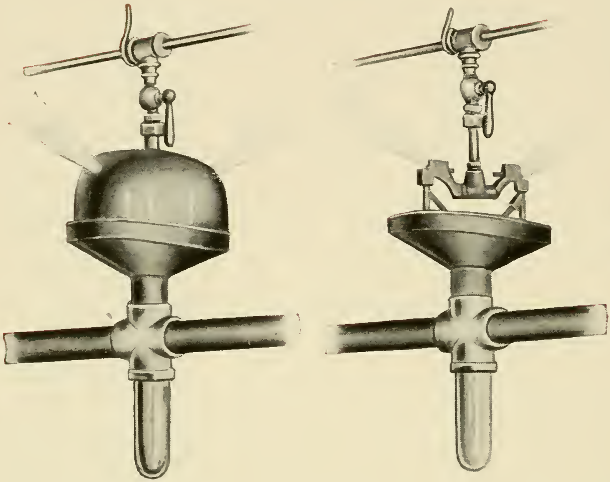


(The equivalent of Turbos; note the greater simplicity of this device,—no handy man, five minutes and a monkey wrench required should a head clog up; simply a push of the one clean-out unstopping both the air and the water orifices at one stroke. For greater obstructions, a thumbscrew cap over the water orifice is removable without a tool and without breaking a union.)

In my first humidifier work several years ago, I worked out an ejector spray nozzle wherein compressed air atomized water, which I thought as truly solved the whole humidifier problem as those who now offer a similar type seem to think; and when I subsequently improved it by adding a push clean-out I was ready to do business, but the relatively small capacity and extravagant power consumption inherent in this type could not be gotten rid of and were points that I knew would not stand the test of time. Of course, those items could be more or less kept in the background by a good press agent, and by advancing side issues, such as by proposing to put in and run a still larger air compressor to clean the machinery with the same equipment, but a little figuring convinced me that independent plants for each purpose were about as cheap to install and vastly more convenient and economical to operate. And so, this device was dropped.

Recently, however, some little demand for it has been cultivated; and so, with the above apologies, we offer such an instrument, or whatever one chooses to call it, that is just as small, no more efficient and more convenient to manipulate than any other of the same kind,—which claims investigation and comparison will substantiate to anyone that is not content with mere appearances but will get to the bottom of the matter.

Cramer Atomizer Humidifiers.



Even more attractive in appearance is my improvement upon the older and better known form of atomizer. It also is provided with push clean-outs; and also, as shown, has a removable cover of seamless drawn sheet copper somewhat larger than one's fist. It is open to the same objections as the other type of atomizer, and is, therefore, only offered with the same explanations and apologies.

Cramer Centrifugal Sprayer.

My humidifier of this type is completely enclosed in sheet metal casings of seamless drawn copper, the same as our other humidifiers; the performance is inferior to the Air Conditioner and the power consumption greater; but we offer it to those who like novelty.

Cramer Evaporative Humidifier.

In these heads cypress evaporative surfaces are used instead of cloths which it is impossible to keep free from slime and smell This humidifier is offered to those who are captivated with theoretical (?) rubbish about molecules and corpuscles at the expense of results,—not to mention those who hold the other view of "Nature's way." (See page 1404.)

Warning.—All our products are patented and users of infringements are liable as well as those who make them.

VII.

CRAMER AUTOMATIC REGULATORS FOR HUMIDIFYING AND HEATING SYSTEMS.

(While the title of this chapter has been obviously selected for advertising reasons, in a broader sense it has been chosen because it is believed that all methods for successfully regulating humidifying systems are tributary to my patents, and may, therefore, with propriety be discussed under the above heading.)

Evolution of Automatic Regulation.

The desirability of automatically regulating humidity and temperature has been appreciated for a great many years. The Patent Offices at home and abroad bear witness to the amount of work that has been expended upon the problem.

The net result of it all has been that, though the regulation of temperature has been successfully accomplished through the means of a number of different types of commercially practicable thermostats, attempts at the regulation of humidity have, until recently, been failures: all depended upon the use of hygroscopic materials for the indicating means, the lack of trustworthiness of which was due to two causes; the first being that humidity affected them to a different extent at different temperatures, and the second, the susceptibility of the surface pores of the sensitive substances to being choked up by dust, lint, etc., a thin coating of which caused the indications to become sluggish and erratic.

The first records in which wet bulb and dry bulb members co-ordinated to perform a hygrostatic function were contained in my patents for doing this through the medium of electric connections. The first type of apparatus constructed under these patents was extremely crude compared to present day constructions, but its performance was sufficient to show its possibilities. The publication of my description of the same before the American Cotton Manufacturers Convention held at Asheville, North Carolina, in May 1906, attracted a great deal of attention, not only in scientific circles, but particularly among textile manufacturers. In spite of the ingenuity displayed in the way of low water alarms, and other precautionary safeguards for the prevention of inaccuracies in the indications of the wet bulb member on account of lack of moisture and other causes inherent in the hygrometric type of instrument, it was found that the instruments would not be a commercial success unless something could be devised to do away with the wet bulb covering. It was evident that another failure would be recorded against automatic regulation unless wet bulb temperatures could be attained without

the medium of any absorbent material requiring frequent changing,—and only approximately accurate at best.

I finally solved that problem, and made possible modern automatic regulators. Naturally enough they are made of different types, so as to suit all conditions. The principles involved in their construction, however, which are covered by basic and fundamental patents, are—

(1) Whatever types of thermometers or thermometric substance are used, there is a dry bulb member and a wet bulb member.

(2) The wet bulb temperature is attained without the use of rags or wickings, by simply saturating or super-saturating air and directing it upon the exposed wet bulb member.

From which it is obvious that the wet bulb member indicates the temperature of saturated air issuing from a humidifying device, whether it be of the central station or of the individual type.

So much for what may also be termed the history of automatic regulation.

Misnomers.

In dealing with any subject that is relatively new, and the available literature concerning which has not reached the standard of accuracy that is the outgrowth of time and familiarity of the general public with the subject, it becomes not only one's privilege but one's duty to point out misconceptions and to expose mistakes. And so, without intention of specifically attacking any particular humidifier, I wish to take exception to the use of the word "automatic" in connection with any type of evaporative humidifier, for it is misleading. The only sense in which such a humidifier is automatic is its variations in capacity under different conditions of humidity and temperature. It might be alleged that this is a certain species of automatic regulation, and if that were all that is claimed for it nothing more would be said; but such is not the case. In the full sense of the word, the term "automatic" is justified only when machines can be made to regulate to predetermined conditions, according to whatever variable scales may be found necessary and requisite for the conditions under which the apparatus was installed,—whether in a textile factory, in an auditorium, or where.

Requirements for Automatic Regulation.

Briefly stated, the maintaining of an absolute or actual humiditiy is useless, and even maintaining a constant relative humidity is by no means what is required of an automatic regulator,—in fact, both are conditions that are seldom, if ever, required of such an instrument.

Whether an air conditioning system is installed for manufacturing purposes or for conditions favorable to health, a variable scale of humidity is desirable, and, indeed, generally necessary.

For example, in the English Cotton Cloth Factories Act (see page 1336), it will be noticed that the percentages of relative humidity vary considerably at different temperatures, the higher the temperature the lower the humidity permissible. While these maximum humidities are permissible, they are by no means desirable, and are seldom maintained except under conditions where extremes of humidity are necessary for some particular purpose. Still, however, as these different percentages at different temperatures were selected with a sole view to the comfort of the operatives, when lower humidities are maintained it is desirable that they should conform to the same scale, to be parallel to it, as it were. And so, in general, in auditoriums, and in fact, in all buildings where humidity is only maintained for conditions favorable to health, a variable scale of humidity is desirable, the percentages of humidity decreasing as the temperature increases.

But, in the case of manufacturing plants, in which humidity plays an important part on account of the hygroscopic character of the materials in process, another and entirely opposite condition of affairs exists. It may be stated as a general rule, certainly so in the case of textile fabrics, that definite amounts of moisture or "regain" (see pages 1348-9 and 1351-94), uniformly maintained in the stock in the various processes of manufacture at all times, are of the greatest importance; that such moisture absorbed by them on account of their hygroscopic properties is greater at low temperatures for the same relative humidity than at high temperatures; and so, in such cases, the scale of humidities is an increasing one as the temperatures increase, instead of a decreasing one, as in conditions favorable to health only.

In textile manufacturing, therefore, while one speaks of the regulation of humidity and temperature, it may be said to refer only to maintaining conditions under which materials in process have constant percentages of regain.

As to the importance of automatic regulation in connection therewith, by referring to pages 1383-94, which can be checked up by test in almost all mills, the actual regain is seen to vary greatly at different seasons of the year even if the mills are equipped with humidifiers, because nature works to help them in the summer and to hinder in winter. Besides, hand regulation cannot possibly anticipate the rapidity of changes throughout the day in any season, for although on some days an automatic regulator will have the water on almost all the time, on other days it will be cut off almost as much, and on other days still it will be off and on as many as one to two hundred times!

While some manufacturers admit that maintaining uniform conditions is of the greatest help in manufacturing, enthusiastically pointing out the savings in the way of better running work, less waste, stronger product, more production and

the like, and even agreeing that a mill selling yarns by weight effects a big saving in regain, nevertheless they do not see that regain cuts any figure in the case of a mill that sells its product by the yard.

But, in all textile manufacturing, there is a certain stage in process of manufacture where weight is translated into measure, pounds into yards, or the like, whether the finished product is yarn or cloth.

Take cotton manufacturing, for example:

Regain in the Various Processes of Cotton Manufacturing.

The actual amount of moisture present in a bale of cotton is entirely a question of the atmospheric conditions existing where it was handled immediately prior to baling. The amount of moisture absorbed by the staple while getting into that condition of equilibrium with the atmosphere at that time and place, where it would neither gain nor lose moisture by being longer exposed unless a change of temperature or humidity occurred, is the same that exists when it is received at the mill; for, on account of the density of the bale, practically no moisture is gained or lost in transit. Very much less water is absorbed by a bale of cotton left standing outside and in the rain than is generally supposed, and that which is absorbed is just as quickly lost again when the bale is exposed to a dry atmosphere, for the effect on the bale has been almost entirely superficial. It is not intended here to condone the practice, far too common, of so exposing baled cotton, for there is really a damage to the under layer of staple, but that is not the question under discussion here. Nor is it contended that cotton held over indefinitely will not ultimately gain or lose weight.

But it is contended, and can be demonstrated to be a fact, that the variations in the amount of moisture existing in different lots of cotton of the same grade and from the same locality are due almost entirely to the different weather conditions prevailing immediately prior to ginning and baling.

Now, the local atmospheric conditions during the ginning season are such that moisture is absorbed by raw cotton in amounts varying from 7% to 13%, with probably average limits of 8% to 9%; such amounts of moisture make it almost absolutely impossible to properly clean cotton in a picker room, for dust, dirt and other foreign matter that separate readily enough when the staple is relatively dry, adhere most tenaciously to damp cotton. And so, very few manufacturers put humidifiers in a picker room, desiring the stock to dry out before working; some of the best manufacturers, and wisely too, go to considerable trouble and expense to provide storage capacity for opened cotton that it may "age," which is largely only a matter of drying out, although in the case of compressed cotton there is a further benefit by giving the

staple an opportunity to assert its natural effort to free itself from the matted condition into which it has been forced.

In working raw stock dyed cotton, "aging" is absolutely indispensible, but for an opposite reason, viz.: to allow it to regain enough moisture from the tinder dry condition in which it has come from the dryers,—a certain amount of moisture being absolutely necessary to give the necessary life and elasticity to the fibres that they may get through the frightfully rough handling they receive in the average picker room without excessive loss and damage both in the picking and in the subsequent process of carding.

And so, cotton "aged" for good working in the picker room will have lost or gained moisture until only 4% to 5% of it has been retained.

In the card room, atmospheric conditions can be maintained so that the stock will begin to regain slightly; and furthermore, it is extremely desirable that effort be made to regulate that amount of moisture so that it shall be practically the same every day.

In the comber room, 6½% to 7½% regain is required that the stock lie dead enough for good work.

In the roving room, it is most advantageous to so regulate the conditions as to secure the greatest possible uniformity of regain, and the same amount every day, that the stock may always go to the spinning room under exactly the same conditions. As to whether a higher or lower regain be maintained in the roving room than in the spinning room, there is a difference of opinion; the best opinion, however, seems decidedly in favor of maintaining the same or a higher amount in the former than in the latter, that the cotton may either not change in spinning, or that it may slightly lose moisture in spinning. My preference, both as a textile and as a humidifying engineer, is in favor of exactly the same atmospheric conditions in both rooms, that there may be absolutely no physical change in the fibre in spinning. To cotton manufacturers, it is only of academic interest to note that in the Bradford system of worsted spinning, there seems to be no question but that the stock should be losing moisture for the best spinning; while in the French system, the stock is either gaining or certainly not losing.

Now, note this point:

It is just here, in the spinning room, that the final adjustment takes place in changing weight of stock into measure; a pound of material is drawn out into so many yards of yarn, according to the count.

Is it not obvious that the spinner who maintains atmospheric conditions in his spinning room so that, say 7%, regain exists in the stock in process saves the difference between that figure and whatever lesser one his neighbor maintains, 5% for instance? And, is that not as truly saved

if the man sells his product in yards of thread or cloth, as if he sold it by weight in pounds of yarn, which must contain so many yards to the pound?

For example:

Maintaining 7% regain, every pound of stock comes to the spinning with 93% dry material and 7% of moisture.

Maintaining 5% regain, there is 95% of dry material and only 5% of moisture.

Then, in each case, the pound of stock is spun into the same number of yards of yarn.

Has not the one spinner saved approximately two bales of cotton in every hundred; or, what is more to the point, has he not made and sold that much more product whether considered as yards or pounds, from the same weight of baled cotton, assuming the two lots to have been exactly alike in every way when purchased?

It has been answered that if thread or cloth, for instance, does regain after it leaves the mill that the maker does not care, for the customer does not insist upon weight; length in yards is all that he demands,—all of which is begging the question, for if that were true, why not make it lighter or heavier still? Again, do not the stockholders of a mill expect the management to save all that is fair and right, and not to throw away any material by furnishing more to the customer than he wants or expects, merely because he doesn't kick? Is it not better policy to give exactly what is represented, no more and no less, rather than more at one time and less at another time, simply because of changes in the weather?

It may be asked what becomes of the difference, and why one man can afford to save it and the other to throw it away. Is one honest and the other dishonest?

In countries where standards of regain exist (see Chapter V., pages 1356-7), the settling value would be the same for both men, and there would be neither a direct gain nor a direct loss, except so far as the conditions maintained by one were conducive to more production, less waste and better quality. For illustration: in England the standard regain for cotton is 8½%; samples would be taken representing the product of each, and both would be worked up to the same settling value based upon that 8½%.

If a standard of 7½% regain existed in the United States, the conditioning house sampling the two lots of yarn would issue a ticket for a settling basis on each as follows:

	No. 1 lot.	No. 2 lot.
Net weight of bundle	10.00 lbs.	10.00 lbs.
Total moisture	7.00%	5.00%
Weight of dry material	93.00%	95.00%
Regain at 7½%	6.97%	7.12%
Correct invoice weight	99.97%	102.12%
Excess or deficiency in moisture	0.03%	2.12%
Correct invoice weight of bundle	9.99 lbs.	10.21 lbs.

Note that the regain is on the dry material, and not upon the weight of sample; also, that both get practically the same for their lot of yarn for the one with the most moisture has more actual pounds to dispose of, but the other fellow gets credit for enough more pounds to put them substantially upon the same basis.

But in this country, no standard of regain does exist; and, therefore, maintaining a lower percentage of regain than the climatic condition of this country averages, and that may be roughly stated to be 7½%, is a dead loss. What I mean to say is that in the manufacturing districts of the United States, both North and South, textiles (whether yarns or cloth) will be found to average 7½% regain the year round; goods figured on that basis will, therefore, be found by whomsoever bought remarkably true to specification, and both the seller and the purchaser are satisfied. But, if made under conditions of say 5% regain, the goods will gain in weight until they reach the average of 7½% regain: the purchaser may be satisfied, but should the seller be? How many converted goods gain weight to compensate for increased length due to stretch; do not the average goods after conversion and stretching gain about enough in weight to compensate for stretch, and if so, is that not that a clear gain that should inure to the mill? This condition of affairs has often been roughly adjusted by the mills making goods or yarns on the light side, for mills generally maintain conditions corresponding to only about 5% regain in spinning rooms,—some through indifference or ignorance, many because of unreliable indicating instruments, many because it has been the custom in the past to put in humidifying systems inadequate in capacity; and all because of the impossibility of hand regulation.

And so, it must be conceded that any goods that gain weight, after leaving the mill, by adjusting themselves to average atmospheric conditions, could better have been made with the proper regain in the first place, and that loss converted into a saving.

Also, that whether the goods are sold by weight or by measure makes absolutely no difference, for if the seller is putting too much dry weight into his measure he cannot get away from the loss by either argument or obstinancy.

As for the atmospheric conditions in a weave room, it is largely a practical question to be ascertained by trial and error; for, fine yarns absorb moisture quicker than coarse ones, and lightly sized warps than heavily sized ones; and the time of exposure of a warp that is run off fast into thin, slazy goods is shorter than one going into closely woven goods; and the time of exposure of a warp on a narrow, fast running loom is much shorter than on a wide, slow one, etc.

From a careful consideration of all of which, not only will

an insight be acquired into a few of the requirements for automatic regulation, but also a conviction of the need for it.

There is no longer any reason for worrying over attempts at hand regulation, nor struggling with intricate calculations to decide what humidities to try to maintain at different temperatures to make the regain right in the different processes. All of these are taken care of in the construction of the Cramer Automatic Regulators; these instruments not only do the work, but do the figuring,—and not only do it during working hours when the help is present, but will do it if desired at night and over Sundays,—thereby lessening starting-up troubles due to changed conditions in the stock in process while things are stopped, to cold lubrication, to tight spindle bands, to increased tensions all through, etc., etc.

By courtesy of the Draper Company, the following extracts from their tests are published:

Effect of Regain on Power Consumption.

In spinning No. 28 yarn with a band tension of 2 lbs. on 1¾″ ring, with 7″ traverse and spindle speed of 8,500 revolutions per minute, the power units are approximately as follows:

Power consumed by cylinder	2.5	per cent.
Bands and bare spindles	50.	" "
Bare bobbins	2.5	" "
Average yarn load	15.	" "
Traveller pull	22.	" "
Rolls, builder and gearing	8.	" "
	100.	" "

As to the effect of other tensions than 2 lbs. band pull, the following shows how the number of spindles per horse power vary:

1 lb. average pull	73	spindles per horse power
1.5 lb. " "	69	" " " "
2 lbs. " "	65	" " " "
2.5 lbs. " "	62	" " " "
3 lbs. " "	59	" " " "
3.5 lbs. " "	55	" " " "
4 lbs. " "	52	" " " "
4.5 lbs. " "	50	" " " "
5 lbs. " "	47	" " " "
5.5 lbs. " "	45	" " " "

From which it is seen that an increase of band pull from 2 to 5 lbs. increases the power due to band pull nearly 40%; or, as the power due to band pull amounts to one-half the whole, an increase of band pull from 2 to 5 lbs. increases the total power required to drive spinning nearly 20%!

Therefore, as the foregoing table shows the increase in band pull due to varying conditions of humidity, or better still, regain, it follows that bands should be carefully put on at the relative humidity at which the work is found to run best, and then that relative humidity should be automatically maintained as nearly as possible. And this is only a power consideration; taking also into account variations in belt slippage makes the need for uniformly maintained atmospheric conditions almost imperative.

Note.—It was intended to publish here some very interesting tests on band pull, power consumption, etc., that we have under way with a very complete apparatus which we have made, especially designed for that purpose; but the investigation has disclosed some unexpected results, too important to be condensed within the small space allotted to it in this book: a special pamphlet will therefore be devoted to it later.

Conditioning Yarns.

Just here a word on the conditioning of yarns is in order. Mills which habitually fail to regulate progressively their regain, make the yarns on the light side and then condition them by steaming, in cellars, etc. But such mills find they can get more moisture into their product in winter than in summer,—as would be expected (see pages 1383-94). All of which shows that automatically regulating conditions in the mill on a mild summer basis would render further "conditioning" unnecessary. For instance, I have always felt that the best compliment my system of Air Conditioning with Automatic Regulation ever got was from a prominent mill man who said that with it: "Every day was like a pleasant spring day." In fact, the yarn finishing and shipping room should be the conditioning room, and all that is required is to maintain there conditions the year round that correspond to the amount of regain desired.

Methods of Automatic Control.

Persons looking into the subject of automatic regulation will at once encounter the terms "Wet Bulb Control" and "Dew Point Control" (see pages 1312-3). A preliminary word or two of explanation is, therefore, in order:

In wet bulb control, the regulator is an hygrostat (see pages 1308-13) actuated by differences in the temperatures of the dry and wet bulb members, nothing being assumed, the temperatures merely being those regularly and all the time indicated by any hygrometer, or psychrometer.

In dew point control, the regulator is an hygrostat (speciously termed a differential thermostat) actuated by differences in the temperatures of the dry and wet bulb members, it being assumed that the temperature of the wet bulb member is that of the dew point of the room,—a condition that seldom exists in summer.

Wet bulb control is applicable to the regulating of both humidity and temperature, and applicable to any type of humidifying and heating system, whether new ones specially designed to work in connection therewith, or an old existing equipment to which it may merely be applied without change and without the discarding of apparatus of value.

Dew point control is applicable only to a central station system of humidifying and heating (see pages 1413-17), and is operative only when such apparatus of which it forms a part is running, the sprays continuously saturating the air going through it and cooling it to its wet bulb temperature,—

and operative then, as already explained, only if the outside and inside conditions happen to be just right so that the saturated outside air, or inside air, or a mixture of both, is cooled to the dew point of the room.

In wet bulb control, the regulation is positive by alternately shutting off and turning on the water and the heat, by closing and opening dampers, or by any other selective means whatsoever, for it makes absolutely no difference whether the water and heat are on or off to the working of the regulator, which only controls the working of those systems, and is neither part nor parcel of either,—entirely separate and independent.

In dew point control the only regulation is by turning on or off heat, and by working dampers, for anything that disturbs the process of continuous saturation puts the regulating device out of commission,—all of which explains the frantic efforts of those interested in that type of apparatus to make it appear that no matter how damp and moist the outside air may be in dog days, that continuously saturating it and pumping it into the mill will not increase the already disagreeable humidity but will, by some stretch of imagination, make conditions right.

As this is a matter upon which mill men are entitled to facts, it is not out of place to give the results of a visit to one of the largest and finest of the new mills in Fall River, which installed a central station apparatus with the so-called dew point control:

June 30, 1909.

(Observations made at 4:30 P. M.)

Observed Outside Conditions.

Actual dry and wet bulb readings, 86° and 78° F.

Dry bulb 86°, Wet bulb 78° hygrometric; 76¼° psychrometric, Dew point 72½°,	Saturated at this temperature contains 9.7 grs. per cubic foot.

Relative humidity 64%.

Actual humidity 8.4 grs. of moisture per cubic foot of air.

Added if saturated 1.3 grs. of moisture per cubic foot of air.

Observed Inside Conditions. (Spinning Room.)

Actual dry and wet bulb readings, 90½° and 78½° F.

Dry bulb 90½°, Wet bulb 78½° hygrometric; 76½° psychrometric, Dew point 71°,	Saturated at this temperature contains 9.8 grs. per cubic foot.

Relative humidity 53%.

Actual humidity 8.0 grs. of moisture per cubic foot of air.

Added if saturated 1.8 grs. of moisture per cubic foot of air.

Desired Inside Conditions. (Spinning Room.)

Dry bulb 90½°,
Wet bulb 80¾° hygrometric;
79° psychrometric,
Dew point 74½°,
} Saturated at this temperature contains 10.6 grs. per cubic foot.

Relative humidity 60%.

Actual humidity 9.0 grs. of moisture per cubic foot of air.

Added if saturated 1.6 grs. of moisture per cubic foot of air.

Remarks:—It is proper to state that one of the officers of the company that installed the apparatus visited the mill during the day with a prospective customer, for the purpose of showing the working of the equipment. Myself and friend arrived at the mill just after the others had departed, and found the mill people had already shut off the sprays and were running the fans at reduced speed with all the windows wide open on the front side of the mill. The shutting off of the sprays was explained by saying that the apparatus was too large for the present installment of machinery; that when the full complement of machinery was installed, it would work better and it would not be necessary to shut off the sprays,—an explanation evidently made to the mill people to excuse the inability of the apparatus to do what was claimed for it.

For, it is quite clear that the larger the apparatus the more favorable would be its performance, as has been stated at a number of places by its makers in their printed publications. Besides, the apparatus was already slowed down, and could have been slowed down to any point where it would work to the best advantage for the amount of machinery installed, as the Mill Company had installed engines for the very purpose of being able to throttle them down and thereby reduce the speed as desired.

The sprays were turned on for our benefit but the observations were taken before the system had been running that way long enough, at the rate of change of air in the rooms, for the conditions in those rooms to have become normal. The attendant frankly stated that he intended cutting the sprays off immediately to keep the humidity from getting too high again.

But it makes no difference whether the sprays had been running only for purposes of showing off the plant or not, for the fact remains that the mill people shut them off because they could not run the equipment with them without having too much moisture, thereby confirming in actual practice what is theoretically obvious from a consideration of the above conditions existing at the time, conditions by no means unusual either, but rather to be expected on the average July or August day.

The above temperatures were read from wet and dry bulb hygrometers of the usual type, one hanging outside a first floor mill window and the other hanging in the center of the

spinning room. The attendant showing us around used psychrometric tables for converting these hygrometric readings into relative humidity, thereby introducing an error of approximately 6% into his interpretation of the conditions existing at the time. In my figures, hygrometric tables have, of course, been used to interpret the hygrometric readings.

As is well known, saturating air by passing it through a humidifier cools it to its psychrometric wet bulb temperature, —a process that adds water to the air as well as cools it.

Bearing in mind which, and with the above data, it is obvious that the system of alleged dew point control could not possibly be operative on this day. For, bringing air from the outside only and saturating it, thereby cooling it to its psychrometric wet bulb temperature of 76¼° increases its actual humidity from 8.4 grs. per cubic foot to 9.7 grs. of moisture per cubic foot. Again, taking inside air and saturating it, cooling it to its psychrometric wet bulb temperature of 76½° increases its actual humidity to 9.8 grs. of moisture per cubic foot. Whereas, it was stated that the Mill Company desired to maintain 60% relative humidity in the spinning room, which calls for only 9.0 grs. of moisture per cubic foot at 90½° spinning room temperature; therefore, it is evident that continuing to saturate either the outside or the inside air, or any mixture of both, would give about 10% too much moisture in the room. Also, while the trade literature of the company installing the plant states that a spinning room can be cooled to within 2° of the outside air, the actual conditions were found to be 4½° above it; but whether the conditions were as actually observed, or assuming that they could hold the temperature of the room even quite down to the temperature of the outside air, matters are not helped any, for the cooler the room is maintained, the higher the relative humidity resulting by such continued saturation with its attendant addition of moisture.

Again, while shutting off the sprays and discontinuing saturating the air and simply blowing it into the room as it existed outside, should theoretically make the humidity only 56%, not increasing its actual humidity at all, still it practically showed by actual tests only 53% with only 8.0 grs. of moisture per cubic foot. The difference between theory and practice in this case is either due to inaccurate thermometers in the hygrometers, or to moisture lost in the air ducts, for it is well known that the lining of brick ducts is hygroscopically gaining or losing moisture all the time, as the air coming through them varies in humidity and temperature.

And so, it is seen that no possible combination of circumstances existed at this time whereby the continued saturation of either the inside or outside air, or a mixture of both, would hold the humidity of the spinning room down to anything like 60%, nor would cutting off the sprays entirely and

blowing outside air in without the addition of moisture get it up to 60%; but it is obvious that intermittently shutting off and turning on the sprays, alternately saturating the air and pumping it in dry, would easily average up to the desired humidity of 60%,—although, of course, in such a case, the alleged dew point control would be out of commission, as it is operative only when the air is continuously saturated.

It is not out of place, however, to mention that the makers blandly propose to lessen the piling up effect of the humidity due to continuous saturation by actually turning steam into the heater coils and heating the air going into the rooms until the required difference has been reached between the temperature of the dry bulb and that of the wet bulb (dew point), a vicious thing to do in a hot spinning room unless it is absolutely necessary, and it was not necessary in this case as simply shutting off the water would have reduced the humidity at once to even below the desired point!

A consideration of any number of similar cases that may be taken to represent a majority of summer day conditions, analizing them along the lines of the above actually observed case, which should be an ideal and typical illustration, for it is such a large one and evidently was put in without regard to cost, shows:

(1) That "dew point control" with its dependence upon assumed relations between outside and inside air, and upon its assumption that by simple evaporation alone a mixture of outside and inside air can be cooled down to the temperature of the dew point of the room, is clearly impossible on the average summer day.

(2) That in spite of strenuous assertions by the makers to the contrary, continued saturation of the air on warm days of even moderate humidity, and blowing it into the room, is impracticable, for it will raise the humidity to too high a percentage.

(3) And finally, that the only system of regulation that is at all practicable is one which deals with the wet and dry bulb hygrometric or psychrometric elements, for they represent temperatures that actually exist all the time and every day; and furthermore, in connection with any system of control, that the only practical and feasible method of regulation is primarily by intermittent moistening, *i. e.*, alternately shutting the moisture off and turning it on as required, and not by continued saturation.

Compare the adaptability for automatic control of my improved construction of Central Station Apparatus (see page 1415) to one of the ordinary type (see page 1414).

In the latter type dew point control has been shown to be a myth in summer; wet bulb control, however, is practicable at all times, although the sprays must be shut off and turned

on intermittently, cooling being discontinued every time the regulator acts.

Whereas, in the former or improved type, half the air is all the time going into the mill, cooled but not moistened when the moisture should be off,—the control simply working a damper throwing the moist half of the air in when moisture is called for and diverting it outside when not required.

Regulator Settings.

It is certain that an intelligent mill man will try different setting points for his regulators until his work runs best in each department, and also that he will check up his conditions occasionally by a psychrometer,—for the convenience of which see tables on pages 1320-32 and 1372-9.

Our regulators have setting points so as to facilitate finding the best points at which to work, it need only be borne in mind that the "G" scale corresponds to the proposed U. S. Regain Standards of 15% for worsted and 7½% for cotton, and that all the other scales simply represent definite steps up or down of approximately ⅔% regain for worsted and ⅓% for cotton.

On page 1336 will be found the English Cotton Cloth Factories Act Table of maximum limits of humidity permissible in English mills. As stated elsewhere, the limits established by that Act were those affecting the health and comfort of the operatives entirely, and simply showed maximum percentages allowed, but which were not to be reached if it could be helped, let alone exceeded; the wide variations in regain therein (regain being the correct measure of atmospheric conditions affecting manufacturing), prove that it was in no wise intended as a schedule of conditions to be maintained for manufacturing advantage. Note that the humidities at different temperatures correspond to percentages of cotton regain from 7.3 to 11.8 and 14.4 to 22.1 for worsted. And yet, many mill men in this country have been for years striving to get the humidity in their mills up to those figures, and all because a maker of humidifiers issues a booklet containing a condensed copy of Hygrometrical Tables (Glaishers), in which tables heavy black type indicates the maximum English limits! No printed explanation accompanies the tables, but users are generally instructed when the humidity gets high enough for the readings of the thermometers to reach those in black type, to shut the system off. All of which leads one to marvel that in an industry which in most respects has been reduced to such a fine art, that until so recently such glaring indifference to the important part that humidity plays in that art could have existed in the minds of those making humidifying apparatus, let alone the mill men who were doubtless doing the best they could with what they had.

Cramer Scales of Constant Regain.

The table following shows the figures at which the regulator is set for the "G" scale. As already stated, the others are parallel to it, either above or below, as indicated by the foot-note. By the term "parallel to it," is meant that with temperature changes, such humidities are maintained for each of the other scales that the regain will be constant, and not a greater or less regain on the same scale as the temperature goes up or down.

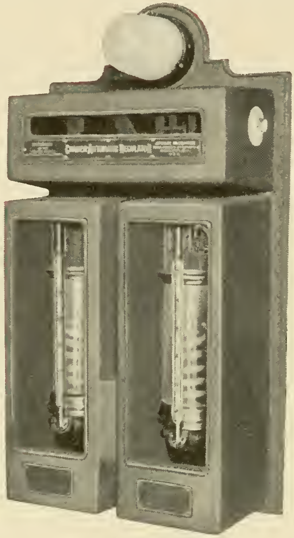
Cramer "G" Scale.

Dry Bulb	Wet Bulb	Dew Point	Actual Humidity	Relative Humidity	Worsted Regain	Cotton Regain
°F	°F	°F	Grs.	%	%	%
100	89	86	12.9	65		
99	88	85	12.5	64¾		
98	87	84	12.1	64½		
97	86	83	11.7	64½		
96	85¼	82	11.3	64¼		
95	84¼	80	11.0	64		
94	83¼	79	11.7	63¾		
93	82¼	78	10.7	63¾		
92	81½	77	10.0	63½		
91	80½	76	9.7	63¼		
90	79½	75	9.4	63		
89	78½	75	9.1	62¾		
88	77½	74	8.8	62½		
87	76½	73	8.5	62½		
86	75¾	72	8.2	62¼	15	7½
85	74¾	71	7.9	62		
84	73¾	70	7.6	61¾		
83	72¾	69	7.3	61½		
82	72	67	7.1	61½		
81	71	66	6.9	61¼		
80	70	65	6.7	61		
79	69	64	6.4	60½		
78	68	63	6.2	60¼		
77	67	62	6.0	59¾		
76	66¼	60	5.7	59½		
75	65¼	59	5.5	59		
74	64¼	58	5.3	58½		
73	63¼	57	5.1	58¼		
72	62½	56	4.9	57¾		
71	61½	54	4.7	57½		
70	60½	53	4.5	57		

(The wet bulb temperatures given above are psychrometric. Temperatures and percentages are given to ¼° respectively; actual humidity is figured to within 1-10 grain of moisture per cubic foot.)

The above scale is chosen as the datum or starting point and corresponds to 15% for worsted and 7½% for cotton. It is arbitrarily designated the "G" scale because it happened to suit the standard scales adopted for use with the Cramer Automatic Regulator, which has 14 parallel scales running from "A" to "N"; the scales above "G" are for higher percentages of regain at all temperatures and those below are for lower percentages. The interval between scales is approximately ⅔% for worsted and ⅓% for cotton.

Cramer Automatic Regulators.



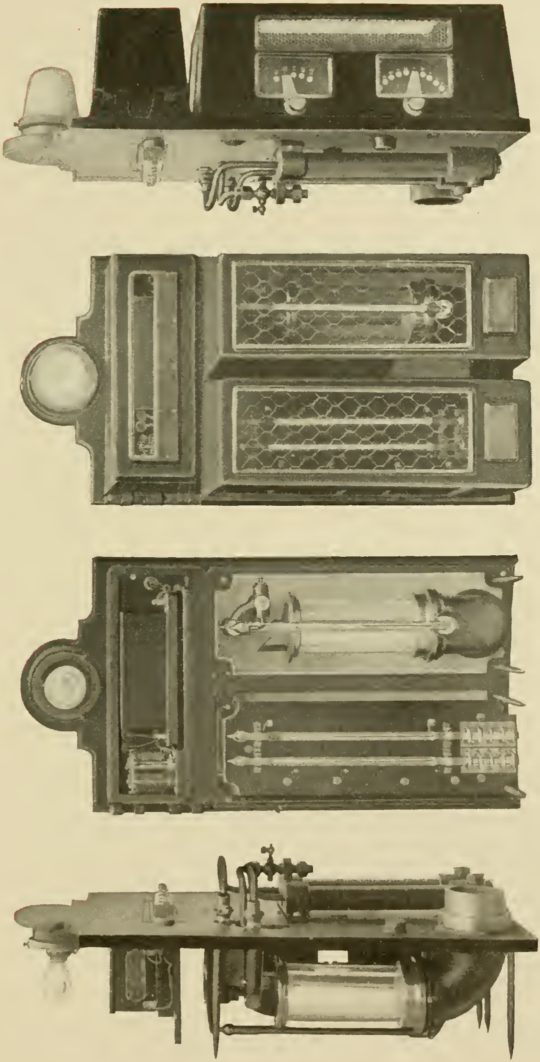
(Mechanical Type.)

From what has already been said, the principles involved in the construction of these instruments and the general details of their construction are no doubt fairly well understood.

There are two thermometers in the left hand or dry bulb compartment, one acting as a thermostat to control the temperature and the other controlling the humidity by acting in conjunction with the wet bulb thermometer in the right hand or wet bulb compartment; the wet bulb temperature is produced by a spray device discharging into a glass cylinder, as shown; in the upper compartment is the actuating mechanism.

The electrical type of instrument is the most sensitive, and in fact, compares favorably with the best scientific instruments produced anywhere, and for any purpose; the mechanical type is just as positive and accurate, but of a lesser degree of sensibility, being therefore specially designed for work where the most exacting conditions do not exist.

Both of these instruments are simple in design, durable in construction and are arranged to be mounted on a column in each room in a mill, with small air pipes leading to shut-off valves suitably placed in the humidifying and heating systems respectively,—thereby controlling the atmospheric conditions in each room separately and independently.

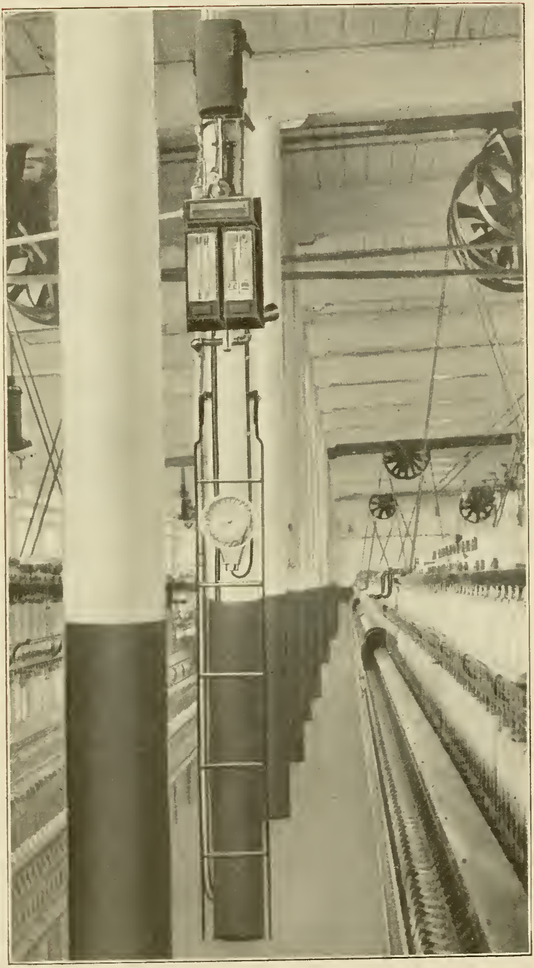


Electrical Resistance Type with Mercury Thermometers.

(Covers on—running position.)

(Covers removed for inspection.)

The only type of automatic regulator based upon the principle of the wet and dry hygrometer or psychrometer,—instruments recognized as standard the world over.



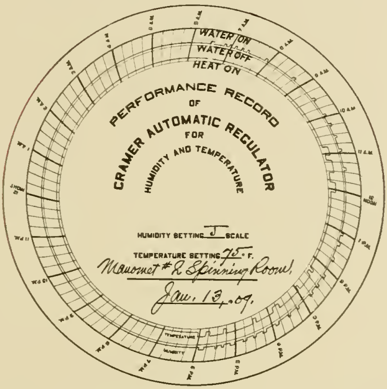
And the only regulator that can be applied to all kinds of existing humidifying and heating plants; no throwing away of present equipments, merely regulation of them.

(View in Spinning Room of Manomet Mills, showing Cramer Automatic Regulator mounted on column, with valve box above from which small air pipes lead to shut-off valves in humidifying and heating systems.)

Providence, R. I. Charlotte, N. C. Atlanta, Ga.

Examples of Results Achieved.

Chart Showing Regulator Performance.



Record of Observations.

Mill Manomet Mills, New Bedford, Mass., Jan. 13, 1909.

(Room) Cotton Spinning, #2 Mill,

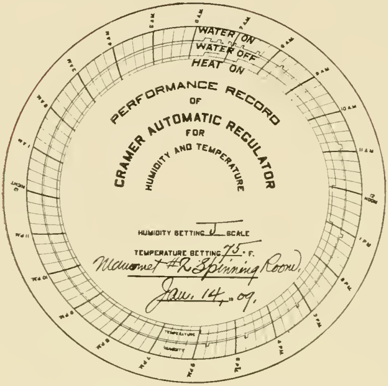
(Floor) 4th with monitor roof.

Time of Observations	CRAMER REGULATOR READINGS							OUTSIDE CONDITIONS							
	Scales		Dry Bulb	Wet Bulb	Rel. Hum	Act. Hum	Regain	Dry Bulb	Wet Bulb	Rel.* Hum.	Act Hum	Weather			
	Heat	Hum.	F°	F°	%	Grs.	%	F°	F°	%	Grs	Wind	Clear	Fog	Rain
8 A. M.	75	J	73	61	50	4.4	6.6								
10 "	"	"	74	62	50	4.5	6.5	25	25	100	1.5	Yes,	Snow		Storm
12 M.	"	"	75	62	47	4.4	6.3								
2 P. M.	"	"	75	62	47	4.4	6.3								
4 "	"	"	76	63	48	4.6	6.4								
6 "	"	"	76	62	44	4.3	6.0								

Instructions.—Under "weather" headings, simply put "Yes" or "No," as the case may be. Be careful to read thermometers to not less than half degrees, and closer, if possible. State whether outside observations were made with sling psychrometer or hygrometer? Psychrometer.

Under this heading many interesting examples could be given; but in order to restrict the size of this volume, which may be already too voluminous to receive the careful attention that I desire to have paid to the details of the subject matter contained, I can insert only examples enough to make clear the remarkable possibilities of automatic regulation.

Chart Showing Regulator Performance.



Record of Observations.

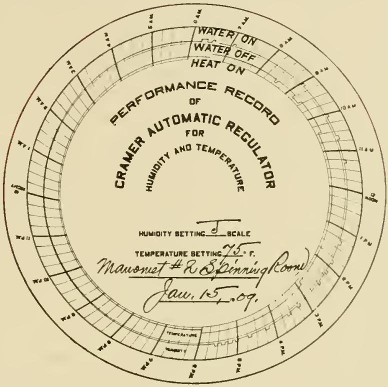
Mill Manomet Mills, New Bedford, Mass, Jan. 14, 1909.
(Room) Cotton Spinning #2 Mill,
(Floor) 4th with Monitor roof.

Time of Observations	CRAMER REGULATOR READINGS							OUTSIDE CONDITIONS							
	Scales		Dry Bulb	Wet Bulb	Rel Hum	Act Hum	Regain	Dry Bulb	Wet Bulb	Rel Hum	Act. Hum	Weather			
	Heat	Hum.	F°	F°	%	Grs	%	F°	F°	%	Grs	Wind	Clear	Fog	Rain
8 A.M.	75	J	75	62	47	4.4	6.3								
10 "	"	"	76	63	48	4.6	6.3	35	35	100	2.4	No	No	No	Yes
12 M.	"	"	76	63	48	4.6	6.3	(Snow changed to rain)							
2 P.M.	"	"	77	64	48	4.8	6.3								
4 "	"	"	77	64	48	4.8	6.3								
6 "	"	"	76	63	48	4.6	6.3								

Instructions.—Under "weather" headings, simply put "Yes" or "No," as the case may be. Be careful to read thermometers to not less than half degrees, and closer, if possible. State whether outside observations were made with sling psychrometer or hygrometer? Psychrometric.

By way of explanation I would point out that the charts shown above simply indicate the times during the day, or night, at which the regulator operated to cut off and turn on the water to the humidifying system and the heat to the heating system to maintain the conditions recorded in the table below. The two broken lines circularly traced around the edge of the chart represent by steps up and down each movement of the water and heat shut-off valves respectively, showing clearly how varying the requirements are,—the in-

Chart Showing Regulator Performance.



Record of Observations.

Mill Manomet Mills, New Bedford Mass, Jan. 15, 1909.
(Room) Cotton Spinning #2 Mill.
(Floor) 4th with monitor roof.

Time of Observations	CRAMER REGULATOR READINGS							OUTSIDE CONDITIONS							
	Scales											Weather			
	Heat	Hum.	Dry Bulb	Wet Bulb	Rel. Hum.	Act. Hum.	Regain	Dry Bulb	Wet Bulb	Rel. Hum.	Act. Hum.	Wind	Clear	Fog	Rain
			F°	F°	%	Grs.	%	F°	F°	%	Grs.				
8 A. M.	75	J	76	63	48	4,6	6,3								
10 "	"	"	76	63	48	4,6	6,3	45	38	51	1,1	No	Yes	No	No
12 M.	"	"	75	63	51	4,8	6,6	(Changed			to	Clear		and	Warm)
2 P.M.	"	"	74	61	47	4,3	6,3								
4 "	"	"	76	63	48	4,6	6,3								
6 "	"	"	76	63	48	4,6	6,3								

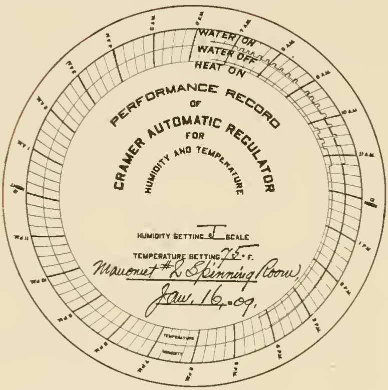
Instructions.—Under "weather" headings, simply put "Yes" or "No," as the case may be. Be careful to read thermometers to not less than half degrees, and closer, if possible. State whether outside observations were made with sling psychrometer or hygrometer? Psychrometer.

tervals between the times the water and heat were cut off and on varying from only two or three minutes in some cases to one or more hours in others.

Attention is directed to the changes in the weather during the four days recorded:

January 13th, below freezing and a driving snow storm.
January 14th, warmer and snow changed to rain.
January 15th, warm and clear.
January 16th, very cold and overcast with strong wind.

Chart Showing Regulator Performance.



Record of Observations.

Mill *Manomet Mills, New Bedford Mass., Jan, 16, 19 09.*
(Room) *Cotton Spinning #2 Mill.*
(Floor) *4th with monitor roof.*

Time of Observations	Cramer Regulator Readings: Scales Heat	Hum	Dry Bulb	Wet Bulb	Rel Hum	Act. Hum.	Regain	Outside Conditions: Dry Bulb	Wet Bulb	Rel Hum	Act Hum	Weather: Wind	Clear	Fog	Rain
			F°	F°	%	Grs	%	F°	F°	%	Grs.				
8 A. M.	75	J	76	58	45	3.7	6.1								
10 "	"	"	75	61	44	4.1	6.0	18	17	84	0.9	Yes	Overcast		
12 M.	"	"	75	62	47	4.4	6.3	(changed during night to cold, overcast and windy)							
2 P. M.															
4 "															
6 "															

Instructions.—Under "weather" headings, simply put "Yes" or "No," as the case may be. Be careful to read thermometers to not less than half degrees, and closer, if possible. State whether outside observations were made with sling psychrometer or hygrometer. *Psychrometric*

Yet, on each day practically the same atmospheric conditions were maintained in the mill, and identically the same that had been maintained since our erecting men left the job early in October, and such as have been maintained since (up to the present writing, June 1st).

It is also in order to point out that these records were taken by the employees of the mill, and sent to me by the officials of the mill.

The above results would tally even closer had the ther-

Mill Mauomet Mills, New Bedford, Mass., Mar. 4, 1909.
(Room) Combing,
(Floor) 2d. —DAY RUN—

Time of Observations	CRAMER REGULATOR READINGS: Scales: Heat	Hum.	Dry Bulb	Wet Bulb	Rel. Hum.	Act. Hum.	Regain	OUTSIDE CONDITIONS: Dry Bulb	Wet Bulb	Rel. Hum.	Act. Hum.	Weather: Wind	Clear	Fog	Rain
			F°	F°	%	Grs.	%	F°	F°	%	Grs.				
8 A.M.	75	I	76	64	51	4.9	6.6								
10 "	"	"	76	64	51	4.9	6.6	50	45	67	2.7	Yes	No	no	No
12 M.	"	"	76	64	51	4.9	6.6	(overcast and very windy)							
2 P.M.	"	"	75	62	47	4.4	6.3								
4 "	"	"	74	62	50	4.5	6.6	45	39	57	1.9	Yes	Yes	No	No
6 "	"	"	74	63	54	4.9	6.9	(clear and very windy)							

—NIGHT RUN—

Time of Observations	Heat	Hum.	Dry Bulb	Wet Bulb	Rel. Hum.	Act. Hum.	Regain	Dry Bulb	Wet Bulb	Rel. Hum.	Act. Hum.	Wind	Clear	Fog	Rain
			F°	F°	%	Grs.	%	F°	F°	%	Grs.				
P.M. 8 ~~A.M.~~	75	I	75	63	51	4.8	6.6								
10 "	"	"	75	63	51	4.8	6.6	Clear and windy; colder							
N. 12 M.	"	"	75	64	54	5.0	6.9	but no temperatures							
A.M. 2 ~~P.M.~~	"	"	75	63	51	4.8	6.6	taken.							
4 "	"	"	75	63	51	4.8	6.6								
6 "	"	"	75	64	54	5.0	6.9								

Instructions.—Under "weather" headings, simply put "Yes" or "No," as the case may b[e]. Be careful to read thermometers to not less than half degrees, and closer, if possible. State whether outside observations were made with sling psychrometer or hygrometer? Psychrometric

mometers been read to fractions instead of to whole degrees; for, a difference of one degree corresponds to about one-third per cent. regain.

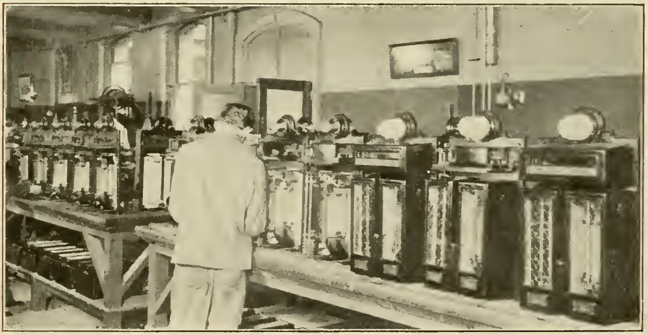
One more example will prove interesting, not only because it represents a typical March day, but because it is a consolidated record for both the day and night runs in a comber room. The outside conditions were observed only during the day time, but the following morning's observations indicated that it was much colder during the night; yet, both the day and the night records could hardly be more alike. One thing that will strike the average mill man is the comparatively low relative humidities maintained to what he has been accustomed to consider necessary,—which emphasizes the difference between the humidity that actually exists, positively maintained by an accurate regulator, and the apparent humidity that is often erroneously indicated by the average hygrometer, of whatever type.

From psychrometer tests of the atmosphere in the different departments of many of the largest and best run mills in this country and abroad, this same observation holds: the humidifiers that really exist are generally lower than the hygrometers indicate and the conditions for the best work are, therefore, usually more healthful than is generally supposed.

General Offices and Shops at Charlotte, N. C.

(See also page viii, in the introductory pages to this volume.)

View in Main Office, Private Offices Beyond.



View in Corner of Instrument Shop, Showing a lot of Automatic Regulators Being Tested Out.

Another View in Instrument Shop.

Seamless Drawing of Sheet Copper, Sheet Metal Shop.

TABLE OF CONTENTS.

Date Due
~~Date Loaned~~
